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# **A model of natural language dialogue**

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**Thesis submitted in fulfilment  
of the requirements for a  
MPhil. in Cognitive Science**

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## *Abstract*

In this thesis I have a threefold purpose. Firstly, I will attempt to argue that the individual utterances agents make in natural language dialogue stem from specific beliefs, goals, and plans and that these interlock with those of other agents in the production of dialogue. I suggest that agents utilise syntactic, semantic, pragmatic and contextual knowledge in this process. Furthermore, that these elements contribute to the utterances speakers make and hearers interpret in the pursuit of their individual goals, and cannot be treated separately. I will suggest that utterances, being intentional behaviour, are sub-components of plans to achieve specific communicative purposes. Following from this, I will present a descriptive model showing how the beliefs and goals of agents contribute to the composing of a logical form for an utterance prior to its syntactic representation. It is suggested that the logical form of an utterance, is composed of elements relating to the agent's beliefs and goals, and includes pragmatic and contextual elements and that these are present prior to the utterance being made and predispose the choice of eventual syntactic components. I do not attempt to model the syntactic form of the utterances but limit the model of the agents to a display to each other of their logical forms and show how these might be interpreted and elicit responses from the hearer in furtherance of their goals. My third purpose is to present a hand-simulated process of this model, to demonstrate how a particular dialogue might be constructed by two agents. This is attempted by ascribing a set of beliefs to them and providing them with specific goals. In the final chapter, the achievements and inadequacies of this research are summarised, and possible improvements and developments suggested in the context of current and future directions.

**To my parents  
Amelia and Sidney Gravett  
who taught me to appreciate words**

" Everyone who looks at conversation in detail finds it engrossing; the fascination of observing speakers dealing with one another is no less compelling than watching the most intricate game or contest - especially if we can approach anything like a full understanding of the rules. It increases our appreciation of the competence of our fellow human beings, even if they do not always achieve the goals they are aiming at, for we in turn remain distant from ours.....For better or for worse, conversation is the human way of dealing with human beings, and we find in it a fundamental expression of our humanity."

Labov and Fanshel - Therapeutic Discourse, (1977: 28 & 361)

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Finally, I want to thank my family, Sheila, Sarah and Lorraine and numerous friends for putting up with me while pursuing this solitary endeavour.

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## **Chapter 1 - Setting parameters**

### **1.1 Research Aims**

This thesis describes research aimed at a theoretical framework for a computer model of natural language dialogue. It has been designed as a theoretical preliminary to future implementations of dialogue systems.

The aim of this study is to make some attempt at understanding how conversation might work and to delineate some of the elements required by a model of conversation between two or more people. Following from this it might be possible to discover characteristics as to how some aspects of conversation might be organised and structured.

The motivation for this research stems from the necessity to discover the psychological processes operating in the behaviour of dialogue and to facilitate greater ease in man-machine interaction.

### **1.2 Introduction**

Conversation involves an interchange between two or more people in which each participant may produce more than one utterance. Each of these contributions build upon previous contributions either directly or indirectly (Hoey 1983: 1) and this characteristic implies that talk between people is organized. However, when one comes to analyse a piece of dialogue it becomes apparent that we take a great deal for granted without thinking very deeply about what is happening. Some idea of the problems encountered can be obtained when listening to a conversation in an unknown language. A steady stream of verbal sounds are emitted by the speakers which are unintelligible and are perceived to be unsegmented. For example, the last phrase, if heard by someone who didn't understand English might hear it as a continuous stream such as, 'andareperceivedtobeunsegmented'. We realize that our own stream of conversation is perceived in this manner by persons who do not understand our language.

Language is never truly continuous, for to convey discrete meanings there has to be discrete units. One of the primary obstacles in learning a new language is deciphering the code which involves finding out what the units are. At the lowest level there are distinctive but meaningless sounds which combine into what we call syllables. Above this level are words and parts of words such as prefixes and suffixes and above this level is the level of syntax which again is a complex of levels in itself.

Language therefore is hierarchic and as each level is examined it gets larger and somewhat more difficult to decide what the structure is supposed to be. Alongside these structural aspects of language are those characteristics relating to meaning - its semantic content. Also, those aspects dealing with language in use - pragmatics and aspects of context that contribute to interpretation and understanding.

This stratification of language provides humans with an unlimited means of resource-fulness for communicating ideas, actions, hopes, feelings, desires, emotions and so on.

Conversation can be markedly different from written text. It can be characterized by false starts, hesitations and repairs. Conversation can contain verbal gestures which convey meaning and are purposive and which do not appear in written texts. Some of the audible gestures can be called lexical and closely resemble words, so much so, that some people regard the audible gestures as 'real words'. For example, some have standard spellings such as 'uh-huh' which can stand for 'yes'; huh? for 'what?'; and 'hmn' for 'I'm unsure'. It is possible to hear a conversation between two people which is coherent and understandable but which when recorded and transcribed into a written form can appear to be disjointed, full of interruptions and hesitations, seemingly, disorganized and without structure.

Conversation is an activity that all of us participate in, probably every day of our lives. We do it with ease and for the most part we do not give much thought to it, language being such a normal and taken-for-granted characteristic of human existence. On reflection then, it is all the more staggering that this most common and seemingly mundane activity has no good theory to explain and demonstrate how it actually

works. This is all the more disconcerting when it is considered how much effort, research, thinking, writing and experimentation has been devoted to attempts to understand language and to construct a plausible theory. It is a problem to which the minds of some of the most eminent scholars have been applied, not only in the fields of linguistics and grammar but also from the domains of philosophy, psychology, and sociology. So wide and so exhaustive has been the investigation into language that it has given rise to several new areas of language research - psycholinguistics, sociolinguistics, neurolinguistics and linguistic aphasiology.

An initial reaction to the vast body of research relating to the study of language might be to think that little further original contributions could be made to the subject and that most of the knotty problems had already been debated and solved. Unless the would-be-researcher has more than a cursory interest in the subject she might be tempted to choose a more limited domain for research and study. Initial reactions though, can be misleading. Any serious student of language comes to realize fairly quickly that although much research into the subject has been done, it has not given rise to any comprehensive or coherent theory that can be used to explain and demonstrate how language works.

It is true that there are many theories about specific aspects of language, some of which help us to understand better what a complete theory of language would need to include and explain. But no theory exists which incorporates the essential characteristics of language into a coherent and consistent theory that could be exposed to empirical testing and validation.

The study of language then constitutes a vast field. Although much is known, much more seems to be hidden and the 'tip-of-the-iceberg' metaphor seems apt in describing what has been achieved and what still needs to be discovered. It is not the aim of this work to provide a comprehensive, coherent explanatory theory. That would simply be pretentious in the present state of knowledge. The domain is large and if advances in understanding are to be made, they are likely to be best achieved by tackling specific and limited areas of the subject for some time to come.

Conversation is only one particular facet of language. As already noted, it is a major characteristic that all of us are very familiar with and more or less take for granted. Unless asked to explain it, we are likely to think that we know how it works and that there is little that needs to be explained. It is only when we start to ask questions about what is actually happening in a conversation or in a dialogue and how the participants manage to make sense of each other, that we begin to understand the complexity of the phenomenon.

### **1.3 The problem**

Some of the following questions serve to identify the difficulties confronting the researcher within the domain of conversation.

When a person directs a question or a comment at another person how does the other person know what is expected of them? How does the hearer know whether the speaker wants some information or simply to say something? How do they know what to reply and what to include in their reply, even whether the utterance needs a reply? Moreover, how does the speaker know that by asking a question she might further her goals and obtain the information or services required?

How does the speaker know how to formulate her utterance so that the hearer can understand and how does the hearer understand anyway? Indeed, how does the speaker know that the hearer has understood her utterance? How does the hearer know what reply to make out of all the possible replies that might be relevant or appropriate? How do words convey meaning in the manner in which they appear to? How does a biological organism such as the brain manipulate ideas, concepts, information and how does it store this knowledge without which, language wouldn't work?

This list of questions and problems is cursory and incomplete but does provide a flavour to the kinds of problems the researcher into conversation needs to address and for which a theory of language would have to account for.

My aim in this thesis is not to resolve or provide solutions to all the foregoing questions, each of which could possibly be the subject of a thesis in its own right, but

to focus on what might be some of the chief characteristics of the dialogue process. In doing so, some hints and insights as to tentative solutions to some of the problems might be discovered.

#### **1.4 Motivations**

The theoretical premise underlying this work is that utterances are generated and interpreted as a consequence of participants pursuing their individual goals and purposes. These goals are the result of participants holding certain beliefs which are pursued by the carrying out of plans. Communication is interaction between one or more participants and the process of dialogue is the manner in which each participant achieves their individual goals.

A major limitation of many previous models is that they often model only one participant of the interaction or that the interaction takes place between a computer program and a human operator. Power's (1974) model appears to be one of the few exceptions to this and one in which two robots are modelled within a communicative task (2.2.2).

What seems to be assumed in many models is that if one participant is modelled, usually the speaker, then the other participant is assumed to operate in the same manner and is generally referred to as a passive listener, seemingly without communicative goals of their own. Explanations in such models give account of how the speaker's utterances are interpreted by the hearer.

This is a useful approach and one which has produced valuable insights. It is possibly the approach that is usually adopted because it helps to simplify the processes involved and makes the explanations less cumbersome. It is an approach most characteristic of language understanding systems. Nevertheless, it does have its limitations as it is a perspective that vests the speaker with the motivation, communicative goals and plans and generally attributes the hearer with a passive recipient role.

A model of dialogue needs to account for the roles of both participants and be able to specify the interaction between the participants and how each achieves their goals (or otherwise) simultaneously in the communicative encounter.

The view taken here is that it is essential to consider the intentions, goals, plans and communicative acts of both participants and how they interact together. Each participant is viewed as achieving goals within the interaction but in a process of dialogue. Only by explaining this process more specifically will it be possible to delineate a more realistic model of dialogue. This view accords with much recent work on discourse and discourse structure relating to intent recognition.

Cohen (1984: 97) has concluded that intent recognition will need to be a central focus for pragmatics and discourse components of future speech understanding systems and argues that computational linguistics will need to develop formalisms for reasoning about speakers' use of descriptions. Grosz & Sidner (1986: 175) propose a theory of discourse that stresses the role of purpose and processing in discourse and suggest that the structure of discourse is composed of three separate but interrelated components; linguistic structure - intentional structure - and - attentional structure.

This work is best described as falling within a 'performance' model of language. Chomsky made a distinction between 'competence' - a person's tacit knowledge and understanding of grammatical rules, and 'performance' - how a person uses language in practice (Chomsky, 1965: 10). Increasingly, as a result of generative grammar being unable to provide further understanding into language, the usefulness of this distinction has been called into question. Many researchers have recognised that a solely syntactical approach to language understanding is impossible and that pragmatic information which is not itself essentially linguistic, is necessary for language understanding (Robinson & Moulton, 1985: 2).

The approach adopted here is that use of language is so closely entwined with knowledge of language that any coherent theory needs to explain how knowledge gives rise to practice and that the competence/performance distinction no longer serves a useful purpose (cf Bara & Guida, 1984: 3; Kintsch, 1974: 3).



## **1.5 Original contribution**

The model of dialogue presented here is of two or more participants who interact together in dialogue to achieve their individual goals and purposes. Each participant has a set of goals and a plan by which to achieve these goals and also a set of beliefs which provide the motivation for their plan and goals. The idea behind this model is that as participants pursue their individual plans and goals in a communicative encounter and as an outcome of their beliefs then dialogue ensues.

What is original about this idea is that both participants to the dialogue are pursuing different objectives and goals. They do not adopt the goal of the other participant which is a characteristic of many other models which incorporate planning and goal elements, but pursue their own plan and objective but within a cooperative framework and in so doing, produce dialogue. The resulting structure and organisation of this dialogue reflects the original goals and plans of the participants.

The emphasis then is not on individual utterances taken in isolation, neither is it on a conversation that has taken place and presented for analysis. The focus attempted here seeks to present some aspects that might contribute to a plausible model of some of the processes that might be involved when two or more people participate in dialogue.

The way in which this is achieved is that the participants within the model are viewed as being equal parties to the communicative encounter. They alternate as speakers and hearers depending on whether they are pursuing a goal or waiting for one to be to be satisfied. Each of them have a limited set of beliefs, a goal to achieve and a plan by which to achieve the goal. Both participants possess similar knowledge structures and routines which enable them to realise their communicative goals.

This research can be viewed as complementing Power's (1974) work. His work was unique in that it was one of the first to attempt a model of conversation employing the concepts of plans and goals for its two participants, characterised as robots. Regrettably, his work and focus does not appear to have been popular or to have been extended but nevertheless, remains a pertinent focus for research. A modest claim of

this work is that it places a similar and equal focus on both roles within a dialogue thus permitting important insights to be made about the nature of conversation and the dialogue process.

While Power's model was limited to two robots cooperating together on a very simple task within a limited domain (sliding a bolt and opening a door), the model exemplified here is applied to more natural and less structured domains. These are a sales scenario between a bookseller and a customer; a negotiation between union and management representatives; and a classroom encounter between a student and teacher.

It is not my intention to present a model which can explain all aspects of conversation and dialogue. Conversation can range from the highly structured and controlled such as that which characterises a court room scene to that which appears to have little or no structure such as the 'chit-chat' experienced at parties or over the garden fence. My intention is to model some of the characteristics involved in task oriented dialogues where the domains might be natural but are highly constrained by the task focus. The emphasis of this work is on the entities and processes involved such as beliefs, plans and goals. Given a different set of beliefs, plans and goals for each participant, the model should be extendable to other domains and might lend itself to less structured and more fluid conversational encounters.

The model itself uses 'frame-like structures' to contain the belief and knowledge entities of the participants and some of the processes within the model such as plan-methods. A trace through the model describes the dialogue process from the formation of a 'plan' for each of the participant's 'goals' through to the display of each utterance until each participant's goal is achieved or aborted and the dialogue completed.

Having identified the research task, and before going further it is necessary to review briefly the varying fields of study relating to the study of conversation and its analysis. By doing so, the present work will be placed within the general field of study and a context identified.

## **1.6 A brief overview of the field of study**

Within the study of natural language, conversation analysis is one of the fastest growing and developing fields. In the last fifteen years numerous papers and books have been written describing various models and their particular virtues.

There are several differing approaches to the study of conversation analysis and its organization and while a superficial comparison of these approaches would suggest that they are quite distinct, the different approaches have some common characteristics which suggest, that on a deeper level of study they resemble each other in their overall conception.

Taylor & Cameron (1987) have made a critical survey of the field and deal with a small selection of the models currently popular. The differing approaches appear to fall into one of five categories or is a variation on one of those categories. The five main approaches to conversation analysis are: the models of the social psychologists; those emanating from the 'Birmingham school' and described as 'exchange structure' models (Coulthard, 1984; Coulthard & Montgomery, 1981); the approach derived from H. Paul Grice and the pragmatists and based on principles and maxims (Grice, 1957, 1968, 1975; Leech, 1983; Levinson, 1983); the ethnomethodological models of conversation analysis (Douglas, 1973; Garfinkel, 1967, 1974; Sacks, Schegloff and Jefferson, 1973) and those of the 'speech act' theorists (Austin, 1962; Searle, 1969).

Other significant approaches to the study of language have come from cognitive psychology, cognitive science and computational linguistics.

From the '40's there had been a developing interest in information technology and considerable theorizing on how information could be processed by machinery (Shannon, 1948). This interest in information processing developed along with the theory of computers and their invention. The theories in these fields had their impact on psychology and led psychologists to focus much more attention on the processes of the mind. The theory and development of computers provided the discipline with a powerful metaphor by which the processes of the mind could be described and possibly explained. The psychological processes which enabled people to cope and

deal with incoming stimuli from the world around them were to be envisaged in terms of computational calculations and information processing.

## **1.7 The theoretical underpinnings for this research**

The model of dialogue presented here falls within the approaches of cognitive psychology and information processing theories of mind. It is therefore influenced by the insights and understanding derived from the disciplines of cognitive science and computational linguistics and of the computer metaphor in general. Cognitive science and the computational model of mind are not without their critics and therefore it is necessary to discuss some of these criticisms in greater detail and to show more explicitly the theoretical under-pinning and impetus for this research and its place generally within the field.

### **1.7.1 Information processing models**

The focus of the information processing approach is that human beings are processors of information and that their subsequent actions and decisions result from this mental activity (Howell, 1982: 3; Lindsay & Norman, 1972; Pylyshyn, 1980: 111; Reason, 1988: 36). An important aspect of this type of theorizing and modelling is to assemble what is known or suspected, into a general model of human performance. A typical model is described by Howell (1982: 4) and which is briefly described here.

Information is received from the environment and processed by the sense systems. It is interpreted by perceptual mechanisms the operations of which are dependent on previously stored information. Following perception, information is translated by other mechanisms into a plan of action that is then implemented through the effectors or motor control mechanisms. Information from the subsequent response is fed back to the system for purposes of adjustment, revision and learning. The component processes of such a system are those of sensing, perceiving, attending, remembering

and translating and response selection. A diagram of Howell's block model is shown in Figure 1.1.

Some of the earlier models portrayed information as passing through a series of structures and buffers, in which processes dealt with the information as it were passing through a pipeline. One of the problems with this type of model was that the processes that went on in the buffers or 'black boxes' were ill-defined or not explained at all. Reason (1988: 38) cites Neisser's caricature of such one-way sequence models labelling them as, 'processing', 'more processing' and 'still more processing'. Nevertheless, these models helped to identify the basic issues facing cognitive theory and to identify the components that any comprehensive model would have to account for. Some of the later models, as discussed by Reason (*ibid.*) seek to overcome the unexplained 'black box' structures of the earlier pipeline models.

The basic issues confronting cognitive theory concern the type of memory system and whether it is a unitary or modularized structure. Whether the processing is localized to a central area or whether it is distributed more widely throughout the system. Also, the manner in which the permanent knowledge structures are represented and organized. There are also issues about control processes. Most models distinguish implicitly or explicitly between controlled and conscious processing or automatic and unconscious processing. Or control is described as being a complex interplay between the two modes. Reason points out that some theorists locate attentional or controlled processing within a restricted 'work-space' of the cognitive system, and that a bulk of cognitive processing is done automatically by numerous specialized processors that are not 'switched' off but remain in varying states of activation in order that activation can be received from other sources other than the limited work-space (Reason, 1988: 43-47).

This discussion of information processing models is brief but serves to provide a context for this research and to identify some of the issues which this work is concerned with.

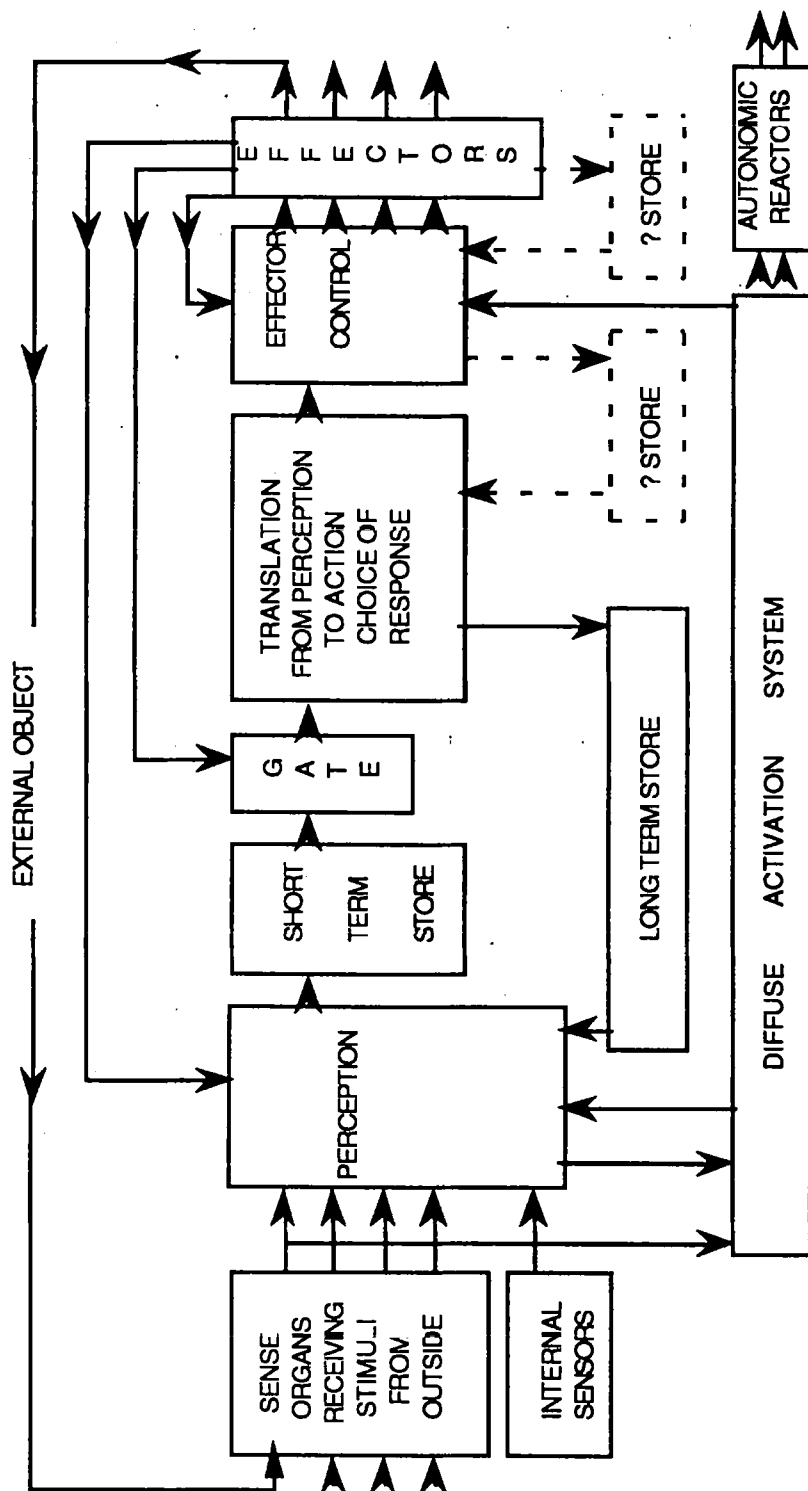


Figure 1.1 A hypothetical block diagram of the human sensory-motor system from Howell (1982: 5)

### 1.7.2 The computational view of mind

The computational view of mind rests on a number of intuitions relating to fundamental similarities between computation and cognition (Pylyshyn, 1980: 111). These intuitions are derived from the fact that both human organisms and computers are physical systems whose behaviour can be described as being governed by rules acting on symbolic representations. One of the basic assumptions behind this approach is that cognitive processes can be understood in terms of formal operations carried out on symbol structures. Pylyshyn argues that certain types of behaviour such as beliefs, tacit knowledge, goals etc., are determined by symbolic representations and that it is this characteristic that suggests that mental activity is computational. He argues that if computation can be viewed as an abstract symbolic process that transforms formal expressions that are in turn interpreted in some other domain of representation such as numbers, then -

"...the view that mental processes are computational can be just as literal as the view that what IBM computers do is properly viewed as computation". (Pylyshyn, 1980: 115)

Pylyshyn argues that this view entails that mental activity can be viewed literally as the execution of algorithms. He sees the modelling of cognitive processes as proceeding in two phases. The first is to emulate the functional architecture of the mind and the second is to execute the hypothetical cognitive algorithm on it. The algorithm is viewed as representing a literal proposal for the structure of the mental process (ibid.).

The computational view of mind has generated considerable controversy (Aanstoos, 1987; Dreyfus, 1972; Searle, 1980, 1984). Both Searle and Dreyfus reject the computational view of mind and strongly criticise Artificial Intelligence (AI), its goals and program, which they view as being the vanguard of the theory.

Searle makes a distinction in his criticisms between strong AI and weak AI. He equates the strong AI view with the brain being likened to a digital computer and the

mind being likened to a computer program and described in a terminology of literally having thoughts and feelings (Searle, 1984: 43). He argues that 'cognitivism' or cognitive science has arisen to fill a gap between the brain and the mind which he calls the mind-body problem or how the mind relates to the brain. His thesis is that in reality there is no gap and that the mind and the body interact and are not two different things. Mental phenomena are simply features of the brain. (Searle, 1984: 26). He goes on to pose the question as to whether computers can think and concludes his discussion firmly in the negative. The reasons being that only brains can cause minds and that computer programs work on the basis of syntax and procedural rules whereas the mind has more than a syntax; it is also characterised by having a semantic content as well.

Furthermore, Searle sees the mind as being characterised by certain intractable aspects, such as 'intentionality' and 'consciousness' both of which are not possessed by computers. He accepts that cognitive science also sees the computer as the right picture of the mind and not simply as a metaphor but which is different to strong AI as it doesn't, or doesn't have to claim that computers literally have thoughts and feelings (Searle, 1984: 43). His interpretation of the cognitive science research program is that thinking is viewed as the processing of information and that information processing is simply symbol manipulation. By this approach, the best way to study thinking is to study computational symbol-manipulating programs, whether they are in computers or in the brain.

The task of cognitive science from this view is to characterize the brain at the level of its functioning as an information processing unit rather than at the level of nerve cells and axons or of conscious mental states. Computer programs are useful therefore, for modelling ideas about mental processes. Model programs can be constructed and tested and if they work certain assumptions can be made that mental processes might work like the programs that have been formed as simulations of their functions. This, according to Searle, is the cognitive simulation view but Dreyfus



appears to question even whether this type of research program can have any value in it (Dreyfus, 1972: xxxv).

Christopher Aanstoos presents a critique of the computational model of thought from the thinking and writings of Merleau-Ponty (Aanstoos, 1987) The main thrust of his contribution is that all thinking is like all consciousness, that is, that it is fundamentally situated in a context or is 'worlded'. According to Merleau-Ponty, to be worlded is to be engaged or involved in situations:

"thereby grasping them from within this involvement with them."

(Aanstoos, 1987: 190).

In this view, human rationality is rooted in human presence rather than being absolute or detached and because thinking is always situated in the human context it is thus 'perspectival'. Aanstoos defines this aspect of Merleau-Ponty's thought as follows:

"...thinking is perspectival, yet its very perspectivity provides thinking its launching, its movement beyond the givens to the latent horizons of possibility and, through them, to further possibles which they imply"

(Aanstoos, 1987: 192)

One of the difficulties of much psychological theorizing in the past was that it either had to be accepted or rejected on the basis of its subjective plausibility and this judgement had to be made by the reader or audience. There were either none or very few ways of rigourously testing some of these ideas. The ideas of Merleau-Ponty on 'perspectival thinking' indicated above helps to illustrate the point that is being made. The ideas sound very fine and plausible but can such ideas ever be tested? Why should we accept Merleau-Ponty's ideas rather than any others? Can these form the

basis of hypotheses that might contribute to a comprehensive and coherent theory of mind? Maybe, but hardly in their present nebulous and subjective form.

Whilst being aware of the deficiencies of the information processing approach the question is begged whether a more worthwhile direction could be pursued. Regrettably, there doesn't appear to be one that either promises to be so rewarding or to provide the necessary insights. The question has been asked as to where psychologists are to turn for a more complex theory? (Miller & Johnson-Laird, 1976: 118). Miller & Johnson-Laird answer their own question and their sentiments with respect to this debate form part of the motivation and justification for this work:

"If one hopes to characterize the psychological processes themselves, the most promising source of ideas rich enough to capture the architecture of this system is the modern theory of information processing. Hypotheses formulated in terms of information processing may also prove inadequate or inappropriate to the task, but they are the best available in our present state of knowledge. We see no feasible alternative for psycholinguistic theory but to pursue these ideas as far as possible" (Miller & Johnson-Laird, 1976: 118)

I do not intend to prolong the discussion further and have raised these issues here to indicate that the information processing approach as it is influenced and dominated by the computational model of thought is not without criticism. Some of the criticisms are a serious challenge both to some of the premises of artificial intelligence and cognitive science and may turn out to be correct. Nevertheless, a premise on which this work is conducted is that the view that human beings can be considered as information processing systems provides a fertile domain for questioning, examining and testing the ideas put forward about mental processes.

The model presented here comes within the framework of cognitive psychology. However, both the information processing and artificial intelligence approaches have

more than a bearing on this work and provide an orientation for thinking about and testing these ideas more explicitly. Whilst a working computer program producing a sequence of dialogue could be a useful objective, the theory underlying such a program is likely to be more important and this work attempts to provide some aspects of such a theory. The emphasis of this research is therefore on the development of theory and the specification of the problem rather than details relating to implementation.

Constructing a model of dialogue is a mammoth project involving most aspects of language, both understanding and processing. Initial plans and ideas in a research project undergo continual revision and given the constraints of time and resources, research programs have to be modified. The model presented here is not a working program as its processes are hand simulated. Nevertheless, the discipline of specifying dialogue as a process has been applied to aspects of the model and have served to identify problems, improve theory and clarify thinking. This work therefore, can be seen as a preliminary exploration of a theory of dialogue to be implemented as a possible program in a future research task.

## **1.8 The use of models in scientific research**

Reference has been made on several occasions in this introductory chapter to the term 'model'. It is necessary to define explicitly what is meant by the term and particularly, how it relates to this work.

The building and constructing of models in order to understand something or to see how something might work is not a new phenomenon and has been an activity that has been resorted to down through the ages. The research literature reveals a plentiful source of metaphors and models that help to illuminate and provide understanding of otherwise complex theories. For example, Robinson & Moulton (1985: 8) borrow an old model to describe their modern 'scope and dependency' theory of language cognition. This is described in terms of an orrery, a clockwork mechanism devised to represent the motions of the planets about the sun and named

after Charles Boyd, Earl of Orrery for whom it was made in 1713.<sup>1</sup> In their theory, the orrery is used to describe the essential features of concepts in an idea which is a prelinguistic structure and how they relate to each other. Though the model is simple the force of it is quite powerful.

In the previous discussion, reference has been made to information processing models and computer models of thought. In fact, the computer metaphor has become one of the richest metaphors for constructing models in the area of cognitive psychology and so used are we to this kind of terminology, it is very easy to take the practice much for granted without explaining what sort of model it is we are using and what can be expected of it. Some researchers do discuss the use and value of models within scientific research and engineering (Black, 1962; Hollnagel, 1988; Wahlstrom, 1988) and it is necessary, to consider some of the presuppositions and implications of this practice in relation to this work.

Max Black in his essay, *Models and Archetypes* (1962) identifies four types of model all of which have problems relating to their use and value: scale models, analogue models, mathematical models and theoretical models.

The purpose behind scale models is to reproduce selected details and features of the original to make it more accessible and to bring the original down to a more workable level. We might want to know how a new airport is going to fit into the environment or what impact a new office block might have on the landscape of a town and so a scale model is reproduced to mirror the essential features of the envisaged original. A major difficulty with this type of model is that any inferences that are drawn from model to original are "intrinsically precarious" and it is normally necessary to require validation and correction from other sources (Black, 1962: 221).

Analogue models involve a change of medium and can be defined as some material object, system or process which is designed faithfully to reproduce the structure of relationships in the original. Once again, Black argues that this too is a model that

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<sup>1</sup> The Shorter Oxford English Dictionary, Clarendon Press, Oxford, 1987 edition.

requires independent validation for the following reason. Inferences made from the point-by-point correspondence of relationships of original to model can give rise to all sorts of irrelevancies and distortions which are presented in an aggravated measure in the model (ibid: 223).

He treats the question of mathematical models at some length and examines their use among social scientists who speak about 'mapping' an 'object system' upon a 'mathematical system or model'. In this context the original field of thought is projected upon the abstract domain of the mathematical theory and the resulting 'model' is viewed as being more simpler and abstract from which to extrapolate inferences. Black points out that it is important to remember that this sort of mathematical treatment does not furnish explanations and can be expected to do no more than draw consequences from the original assumptions. The danger of making simplifications for the needs of success in the mathematical analysis can entail:

"a serious risk of confusing accuracy of the mathematics with strength of empirical verification of the original field" (ibid: 225).

Mathematical models, scale models and analogue models differ substantially from theoretical models. Black argues that both scale and analogue models have to be put together but that the architect's 'hypothetical' model is nothing at all and the imaginary analogue models will not show us how things are likely to work in the real world.

The difference between these models and a theoretical model is that the theoretical model is not literally constructed but its value and strength consists in a certain "way of talking" (ibid: 229). This type of model does not have to be constructed and needs only to be described. This brings with it certain advantages as well as limitations for the model builder. Whilst she may not be distracted by irrelevant relationships and properties of the model, it does deprive the model builder of the discipline of actually constructing a model and of the inherent controls in this process. One of the difficulties of working with a theoretical model is that without independent tests or means of

verification, inconsistencies can develop between elements of the model. There is then a danger of making inappropriate assumptions.

Black suggests that there are formidable risks to be taken in using theoretical models and that any particular model may amount to nothing more than:

"a strained and artificial description of a domain sufficiently known otherwise" (ibid: 237).

However, he argues that the use of metaphor can often be valuable in achieving insight and that the role of models in scientific research have a similar value to the use of metaphor and the role of imagination in literary endeavour. In fact, he views imagination as being one of the most powerful factors in all research:

"For science, like the humanities, like literature, is an affair of the imagination" (ibid: 242-243).

The "way of talking" associated with the theoretical model involves the imagination. Though there are risks in this type of theorizing such models can often help us to see and make new connections.

This cursory review of Black's stimulating essay does not do justice to his ideas and arguments but some of the most salient points are used here to illustrate the nature and use of models in scientific research and some of the problems associated with this method. The purpose of this discussion for the present work is to identify the sort of model which is being constructed here.

My work can be categorized as a theoretical model and is motivated by the principles, as identified by Black, on which this type of model is put forward. However, imagination has not been allowed unlimited freedom as some attempt has been made to test and validate elements and relationships within the model for the purpose of self-consistency. This has been achieved in some measure by imposing

certain constraints on the model. That is, the model must be viewed as a process that is computable and lends itself to explanation in computable terms or is able to be implemented as a computer program. This has not always resulted in success but the problems encountered are identified and discussed as well as the insights and connections that can be made from it.

## **1.9 Preliminary definitions**

Up until now I have used a number of terms such as conversation and dialogue without defining them and it is necessary to define how terms are to be used in this thesis. The term dialogue is not frequently used within the literature and not generally defined when it is, nevertheless, it is used as a descriptor for some models and also as a term for describing conversation. The terms most generally used are 'conversation', 'discourse', 'text', 'speech' and 'talk'. In much of the research which relates to the study of spoken interaction, most studies assume the reader to have a knowledge of what conversation is. Being the primary basis between persons for direct social interaction, conversation is assumed to be self explanatory and not usually requiring more specific definition. For example, Allen & Guy introducing the subject of Conversational Analysis describe it in the following terms:

"Conversation is the primary basis of direct social relations between persons. As a process occurring in relative time, conversation constitutes a reciprocal and rhythmic interchange of verbal emissions. It is a sharing process which develops a common bond"(Allen & Guy, 1974: 11).

The study of conversation and dialogue comes within the boundaries of 'discourse analysis', a term initially coined by Harris (1952: 355) for the study of text and which continues to be used through to the present day (Hoey, 1983: 34; Stubbs, 1983: 1). However, Harris, Hoey, Stubbs and others use the term fairly broadly to label modes

of study that often are at variance with one another. Stubbs (1983: 1) makes the point that the term 'discourse analysis' is somewhat ambiguous and suggests that generally, it refers to attempts to study the organization of language above the sentence or the clause and therefore its focus is on larger linguistic units such as conversational exchanges and written text.

Stubbs uses the term 'discourse analysis' in the sense of referring to the linguistic analysis of "naturally occurring connected spoken or written discourse" (Stubbs, 1983: 1). Though he admits that the use of the terms 'text' and 'discourse' which are used within the wider term of 'discourse analysis' are both ambiguous and confusing, he does not draw any firm distinction between the two.

Van Dijk (1977: 3) draws a very clear distinction between 'text' and 'discourse', regarding 'text' as an abstract and theoretical unit underlying what is usually termed a 'discourse'. In this usage 'discourse' is viewed as a 'text' that has been externalized by an author, in the sense of it being in a spoken or written form.

None of these distinctions are very useful for present purposes and as I am not concerned with 'text linguistics' per se I do not propose to use any of these definitions and will not discuss this further. I will use the term 'utterance' to refer to a contribution made by a participant and the sequence of utterances between two participants as a 'dialogue', the latter term which is clarified below. A dialogue in its written form is called a dialogue-text.

Crystal (1985: 96), in his Dictionary of Linguistics describes 'discourse' as a term used in linguistics to refer to a continuous stretch of language larger than a sentence, especially spoken language. Surprisingly, he has no entry for the term 'dialogue' and I can only assume from this omission that it is used less frequently both in general parlance and also in the literature, rather than any particular arguments against its use.

The Shorter Oxford Dictionary (1987) has two meanings for the substantive use of the word 'dialogue' whereas for 'conversation' it has ten. The range of meanings for the latter include; - 'the action of living or having one's being in or among'; 'sexual intimacy'; 'behaviour or manner of life'; 'interchange of thought and words';



'familiar discourse or talk', and so on. With such a range of different meanings it would seem that it was a term best avoided. Nevertheless, it is a term which has a very common usage and therefore is easily understood. To avoid its usage in this study would pose some major difficulties as its use throughout the literature is extensive. I therefore, use the term 'conversation' when discussing the subject in general and in examining studies of other writers and researchers. Following from this, I use the term 'interaction' to refer to the conversational exchanges which take place between particular participants.

My objective in this study is to model the spoken interaction between two or more people and attempt to specify how this might be achieved. Within the constraints of the model I do not wish to use the term 'discourse' as again, this has several technical and everyday meanings which include such senses as that of, 'speech', 'talk', 'narration', 'a spoken or written treatment of a subject at length' and so on, which make it insufficiently tight as a concept for this study. For the specific purposes of both describing the model and discussing its objectives I use the more parsimonious meaning encapsulated in the term 'dialogue'. From its origin in Latin and Greek this word has gone through minor change, if any, and its primary meaning is appropriate for use when discussing the model at a later stage. It is simply, 'a conversation between two or more persons'.

The use of this term does not limit the model to describing the interaction of two people only as it is possible for the model to be extended to include other participants. What it does delineate is the boundaries within the interaction represented by this particular model. That is, 'dialogue' refers to only two speakers at a time whether it is speaker A with speaker B, or between speaker A and speaker C. Whilst to all intents and purposes such a scenario could be described as a general conversation, the focus of this study is on the links that are made between one speaker and one other at any one time. The contention of the model is that if these links can be demonstrated to be appropriate, cohesive and understandable then the total dialogue produced will demonstrate structure and be understandable in terms of beliefs, plans and goals. How

many persons can be party to a conversation before coherence and cohesion begin to be strained depends on the participants, their goals and the material being discussed but which is not a matter that I need to address at this stage.

I am concerned with a model of natural language dialogue, so it is reasonable that I will have cause to refer to 'speakers', 'hearers', 'authors', and 'audiences'. I use the term 'speaker' to refer to the person who produces the utterance. The term 'hearer' refers to the one who is listening and seeking to understand the speaker. The roles of course are interchangeable within the flow of dialogue. To refer to a specific section of dialogue the term 'dialogue-text' will be used as previously noted. The term 'author' is used to refer to any specific utterance of the dialogue-text produced by that speaker. The term 'audience' is used to refer to one or more persons that are designated by the speaker to receive an utterance and who attempt to understand it.

#### **1.10 Why a model of dialogue?**

The view of this study is that dialogue takes primacy over monologue whether written or spoken (Hoey, 1983: 27). I do not wish to denigrate in any manner the volume of important work that has been done in the area of monologue as many insights and much valuable knowledge has been gained from this field of study. But neglecting the study of dialogue is likely to limit advances to a more complete understanding of such an integral and common aspect of human interaction.

Rosenberg (1980: 11), has argued that natural language understanding with computers will require a greater understanding of the nature of human dialogue and makes the observation that there are no working systems that incorporate the spectrum of ideas relating to 'discourse analysis'. Regrettably, thirteen years on, this still seems to be the case and the necessity is more pressing than ever. Winograd (1980: 229), indicated that his work then, was moving towards the domain of human action and interaction and saw the utterance as being a linguistic act that has consequences for the participants, not only for their immediate actions but also to commitments for future action.

This work is situated within a similar context of thinking about human action. Human dialogue is viewed as being a purposive, goal oriented activity which results from the beliefs and planning activity of its users.

An oft used metaphor is that it takes 'two to tango' and this applies to dialogue. An analysis of each partner's steps and arm movements in the 'tango' might provide a plausible and correct description of what was happening in this activity. It might be possible to construct individual models of both partners to see how both of them danced. This might be an appropriate way to start analyzing their actions but somewhere along the line the two models would have to be brought together to see whether their individual actions married together and became a true reflection of the 'tango'. If they didn't, the interaction could be disastrous.

In language understanding we know much about the abilities of individual speakers and hearers but a model of them interacting together is a pressing requirement. The focus of this work is on that 'dance' which takes place between participants in a dialogue; how they each derive their goals and purposes from the interaction and the ways in which these are achieved. A comprehensive, coherent theory and model of dialogue is an imperative requirement and long overdue. This work does not claim to be that theory or model but a contribution to some of the elements and components that will be required by such a model. In that sense it is an exploratory foray into the issues at large.

### **1.11 A brief reader's guide**

In the following chapters the elements required by such a model are identified.

- Chapter two explores the basic assumptions on which the theory and model is based and provides a review of the relevant literature and some previous research.
- Chapter three discusses the theory of rational interaction under-pinning the model and the theoretical elements required in such a theory.

- Chapter four forms the basis for the animated description of the model and identifies its components.
- Chapter five is a hand simulated trace of the model in action and traces the participant's goals through to their outcome in utterance form.
- In the last chapter the model is evaluated and its conclusions discussed. Also, relevant applications stemming from the research are noted and future research directions are identified.

**-oOo-**

## **Chapter 2 - Minimal assumptions for the development of a model of dialogue**

A difficulty that a researcher is presented with in the domain of language is not only the extent of the source material she needs to be acquainted with but also the plethora of theories and ideas about language that have a bearing on the research topic. Existing theories and conclusions influence and guide the choice and design of any research that follows. Some basic assumptions underlie most, if not all research, having been derived from prior observations and findings and as a consequence influence both content and outcome of any project.

Assumptions are not always clearly stated but it is an essential task of this project to identify the major themes and theories relevant to the area of study. What I wish to do in this chapter is first to set out the arguments for the minimal assumptions that underlie the theory and model of dialogue presented in this thesis. Then to identify and discuss related research and models of dialogue. Because the extent of the research and literature is so large the review presented here is limited to the purpose of setting the present research in context. The reader is referred to the report by George Kiss (1986) for a comprehensive and extensive review of work relating to high-level dialogue in man-machine interaction.

### **2.1 The six major assumptions underlying this work are:**

1. The primary role of natural language is communicative.
2. Following from 1 conversation is purposive and rational behaviour.
3. Following from 1 and 2 conversation takes place within a social context and can be viewed as a cooperative activity.
4. Following from 2 and 3 conversation is characterised by regularities rather than rules or principles.
5. Following from 2, 3 and 4 conversation is intentional and

plan-based behaviour.

6. Following from 4 and 5 conversation is inherently organized and structured.

### **2.1.1 Assumption 1 - The primary role of natural language is communicative**

I am assuming that my reader will accept the assumption, that the primary role of natural language is communicative and without further justification or claims on my part other than an appeal to common understanding. In the present state of knowledge natural language is viewed as being a uniquely human activity which allows humans the capacity to communicate in a unique manner. As has already been noted (1: 9), conversation can be described as being "the primary basis of direct social relations between persons" (Allen & Guy, 1974: 11).

The primary role of natural language is to enable humans to communicate something about themselves and their experience to others. It is likely to have other functions but which I do not propose to address here.

### **2.1.2 Assumption 2 - Conversation is purposive and rational behaviour**

One of the most human activities is that of talking to each other. Whatever term we use for this activity it relates to the everyday situations in which two or more people address each other for a period of time and communicate something of themselves to the other. People can use conversation to express their feelings and mood; to state their beliefs or doubts; to obtain information and knowledge and to convey feelings and attitudes. Conversation can be an instrument to obtain what is wanted and to express many dimensions of human experience. It appears to be a behaviour that is rational and purposive and which implies that participants use conversation in an organized and orderly manner to obtain and achieve goals.

The use of the word 'purposive' to describe conversation requires further explanation. Humans are aware of the characteristic of purposiveness and so are able

to appreciate and alter their environment in an explicitly purposive manner. This they do by studying the environment and then imposing new forms upon it. It is in this sense that I use the word 'purposiveness' in relation to conversational behaviour. The point of the argument is that when a human uses natural language in the communicative act she must be aware of two things. Firstly, the purposive nature of the instrument she is using and secondly, the objective or change in a particular environment which she seeks to achieve by using the instrument.

### **2.1.3 Assumption 3 - Conversation takes place within a social context**

Much research into language, including the study of conversation, often focuses only on the structural, grammatical and semantic characteristics. Within such a focus an assumption is often made that conversation consists of units, the sequencing of which are governed by some kind of rules. From this view, the major problem for the analyst or researcher, is to isolate and identify the units and rules which comprise conversation. Once this difficulty is resolved the process of conversation will then be open to explanation.

What is largely ignored in such a program, is the social context in which conversation takes place. A consequence of which is that we are often left with loose ends and some imponderables in our theories that simply do not fit together or match the empirical evidence. It needs to be emphasised that conversation is inextricably linked to a social context and any conversation or dialogue can only be properly understood in relation to the context in which it has taken place.

Every conversational contact is oriented toward some communicative goal which contributes to its continuity and which goals may be influenced or motivated by feelings and emotions or stem from obligations. While it is not my purpose to attempt to model these latter characteristics, it is accepted that they can have a motivating role within communicative interaction and that these factors help to influence and characterize the beliefs that lie behind a person's purposes and goals. It is the beliefs of

the participants that form an integral part of the model presented here and it is acknowledged that beliefs are affected by these other more intangible characteristics.

Sociological perspectives of conversation and social interaction which focus on the wider context in which interaction takes place have contributed many important insights to our knowledge of language and its use. Among some of the studies referred to in the literature a particularly significant contribution is the work of Erving Goffman. He has made an analysis of the ritual elements that appear to be a part of social interaction, particularly face to face communication (Goffman, 1955: 213-231; and 1969).

His analysis of these ritual elements suggest that people have an attachment to a particular 'face', face being an image a person has of themselves in terms of approved positive social attributes. A particular 'face' in interaction can be easily disconfirmed or confirmed and which is a reason that each participation in a contact is a commitment. A person is assumed to have feelings for the face of others as well as one's self and the amount of feeling that one has for any face in particular is proscribed by the rules of the particular group and defined by the situation. When a person presents an image of themselves that is consistent and supported by the judgement of other participants she is said to be in face, to have or to maintain face. The line a person is maintaining within a contact is viewed as being of a legitimate institutionalized kind and the face presented is seen as being located in the flow of events rather than in, or on, the body of the person.

Some other researchers, including linguists and anthropologists have developed lines of enquiry from the ideas of Goffman and some of these argue that there are universals in language use that govern politeness phenomena and face threatening behaviour across cultures. Brown and Levinson have developed a more formal model of how this works in practice and use cross cultural examples to demonstrate their theory (Brown & Levinson, 1978; 1987). Labov & Fanshel (1977: 26), are researchers who confront the problem of emotions and obligations and adopt a view of conversation as a type of interaction which takes place within a social framework.



They argue that the rights, duties and obligations of each partner within a conversation must be understood if we are to understand any specific discourse rules that might underlie conversation.

Furthermore, Halliday (1973, 1978) has drawn attention to the fact that speaking and understanding language always takes place in a context. We do not 'know' our language simply as an abstract system of vocal signals but in the sense of knowing how to use it. The form of knowledge we have about language is knowing how to behave linguistically and knowing how to speak to other people. Embedded within this knowledge of how to use language is how to choose the forms of language that best serve our purposes in particular situations. We do not use language in isolation and Halliday has suggested that language comes to life only when functioning in an environment. It is used in scenarios that have a context, of persons, relationships, actions and events, those things from which meaning is said to derive. From this perspective language always has a 'context of situation' (ibid., 1973: 49). This basic concept was one originally suggested by Malinowski (1923) and subsequently elaborated by Firth (1957), both of whom appear to have had considerable influence on Halliday's ideas.

Conversation then, takes place within a social context. The foregoing would indicate that participants to a conversation share in this social context to varying extents. That is, each of the participants hold beliefs about the context that forms a background or motivates their conversation. The extent to which participants share information about the context suggest that they have 'mutual knowledge'. Furthermore, the constraints that stem from the social context suggest that conversational activity has another dimension, which is that it can be viewed as a cooperative activity. Both ideas are important and discussed at length in the literature. It is necessary to discuss both concepts and how they will be used in this work.

### 2.1.3.1 The problem of mutual knowledge

Communication requires a high degree of coordination between speaker and hearer both to the choice of language and context. An explanation of how this coordination is achieved is to use some notion which views the participants as 'sharing' worlds together. For example, Cohen & Levesque (1980: 263) argue that in order to communicate, speakers must make their plans shared or public knowledge, following Schiffer's (1972: 144-148) argument that the recognition of intention must be mutually believed thereby avoiding an infinite regress of intending that one recognize an intention.

Hobbs & Robinson (1979: 316) make the point that normally, a speaker will choose the descriptions of entities involved in an utterance in such a way that the listener will easily be able to identify the entity referred to. That is, properties the listener knows about and words that are familiar to the listener are generally and ideally used by the speaker. In relation to this, Clark & Marshall (1981: 32) in their discussion of definite reference point out that to be "felicitous", a definite reference must use only properties in the speaker's and hearer's domain of mutual knowledge. However, Hobbs & Robinson (1979: 317) make the point that in actual performance speakers can be quite casual in choosing their descriptions because there is always an opportunity for repair.

The notions of 'mutual belief spaces' or 'mutual knowledge' are significant in this context and seem to be widely accepted without much criticism. However, Sperber & Wilson, (1986: 21), reject the construct of 'mutual knowledge' believing that it is untenable and has no counterpart in reality for the reason that the term itself is a misnomer. That is, that the knowledge that different agents have is peculiar to themselves and cannot be considered as being 'mutual' in the true sense of the word. Instead, they opt for a notion of 'mutual manifestness'. They argue that an individual's total cognitive environment is the set of all the facts that she can perceive or infer - that is, all the facts that are manifest to her or are capable of being manifest to her.

I do not intend to debate the issue as to whether the notion of 'mutual knowledge' is an "empirically inadequate notion" (Sperber & Wilson, 1986: 38) but what I do wish to note is a characteristic that Sperber & Wilson acknowledge and that is, that the communication process itself gives rise to shared information. I do not intend to discuss the sense in which humans share information or the extent to which they share information about the information they share. What is important about this argument is that participants who share the same language and linguistic community, share a pool of knowledge in common with each other. Whilst they will have their own individual perceptions of this knowledge these perceptions will overlap sufficiently with those of others, to provide a common domain by which to make sense of each other's utterances. It is in this sense that this work will use the term 'mutual knowledge' although the term 'shared information' will be preferred.

The interested reader is directed to the texts and related debate concerning Sperber & Wilson's ideas on this subject and to compare these with the views of Taylor and Cameron who argue that the similar principle of "intersubjectivity" should be abandoned (Sperber & Wilson, 1986, 1987; cf Levinson, 1989; and Taylor & Cameron, 1987:162). My purpose for introducing the subject of 'shared information' is that it is tied intimately to the model a person has of the other person's plans, intentions, beliefs and utterances and is therefore relevant to this work.

The other important concept arising from the social context of conversation and the allied idea of agents sharing knowledge and information together is that of 'cooperation'.

#### **2.1.3.2 The context of cooperation**

Communication is a process that takes place between agents within a social context. Grice (1975) has suggested that the process of communication can generally be viewed as being a cooperative venture. It is necessary to explain what is meant by 'cooperation' in this instance.

Galliers (1989: 61) is particularly concerned with the concept and postulates a cooperative model of dialogue which acknowledges multi agent conflict. Her views about the place of cooperation and conflict within dialogue differ from the present work and will provide a background for discussion as well as for defining the concept for use in this model.

Areas of artificial intelligence research which are concerned with multi-agent planning or joint problem-solving are faced with the issue of cooperation. Galliers (ibid: 61) argues that the principles of cooperation have not been rigidly worked out, neither are they explicitly expressed in these systems, whether they be human-computer interaction (HCI), or machines networked together as in distributed artificial intelligence (DAI). The thrust of Galliers' argument is that the concept of cooperation is generally assumed and is implicit in these systems and theories but whose emphasis is elsewhere. Her major contention is that there is a lack of recognition in existing work of the nature of conflict and that conflict is an important component of cooperation. Because of this deficiency, she argues that:

"...the existing notions of cooperation implicitly or explicitly incorporated in current artificial intelligence research on cooperative multi-agent systems, are simply inadequate to real-life application"  
(Galliers, 1989: 61).

As the model presented here is concerned with a real-life application of dialogue and is extendable to multi-agent interaction this suggested deficiency in the research has a bearing on the present work.

The major criticism of Galliers to the accepted notion of cooperation which is implicitly encoded in much of the existing work, is that agents have a common goal and that assumptions of benevolence and helpfulness on the part of agents are made without any recognition of the place of conflict. This may in some cases involve each

agent in a multi-agent system having a goal to achieve the same end result, but in other cases, an agent might take over the goal of another agent and pursue it as their own.

One view of cooperation that is sometimes adopted is that of sharing, where the agents who are in complete agreement to their goal, share the tasks necessary to achieve it (Galliers, *ibid*: 124). This view of cooperation incorporates the concepts of 'helpfulness' and 'mutual consideration'. Allwood (1976) postulates a definition of ideal cooperation as:

"A number of interacting normal rational agents are said to be engaged in ideal cooperation to the extent that:

1. they are voluntary striving to achieve the same purposes,
2. they are ethically and cognitively considering each other in trying to achieve these purposes,
3. they trust each other to act according to 1 and 2 unless they give each other explicit notice that they are not

(Allwood, 1976: 56-57).

According to Allwood the characteristics of cooperation include mutual consideration as well as having a common purpose. Galliers (*ibid*: 124) suggests that previous computational research in cooperative interactions has embodied these notions of helpfulness and mutual consideration as the recognition of another's goal. Agents, accordingly, are designed to always be cooperative - that is, helpful and ready to take on the other agent's goals as their own. It will be seen later that this is a characteristic assumed by Power in his model (2.2.2) where either Mary or John communicate their goals to the other in order to obtain cooperation for the joint planning exercise of opening a door (Power, 1974). Appelt in his KAMP system also assumes that:

".....if one agent is helpfully disposed towards another and knows that the other agent intends to bring something about, he then adopts that goal as his own" (Appelt, 1985: 49).

Galliers challenges these assumptions by asking the question as to whether any condition or circumstance exists in existing research where helpful agents do not necessarily adopt other agents' goals merely by virtue of recognizing their existence. She cites Cohen & Levesque's (1987) work which stipulate that agents are defined as helpful in adopting other's goals, but only as long as they do not have any existing contradictory goals of their own. She acknowledges that this stipulation is likely to be true of the other work mentioned, but that it is not explicitly stated and that the implicit assumption generally seems to be, that agents simply do not have conflicting goals of their own. She rejects what she describes as the existing notions of cooperativity used in recent AI research and incorporates into her theory the premise that:

"one important component of cooperative interaction is the joint resolution of conflicts" (Galliers, 1989:65).

The definition of cooperation she gives is:

"... cooperation.....includes a common goal which may be generated as a result of recognizing it as another's goal, but this is conditional upon the agent's own preferences. Helpfulness is retained as an important element of cooperation by commitment to the common goal being relative to the other agent having it as a goal. It is the inclusion of preference which so importantly removes benevolence from the definition, and replaces it with agent autonomy" (Galliers, 1989: 67-68).

A claim of this present work is that the nature of cooperation as it concerns communication is being misconceived when it is argued that one of its major objectives is that of a common goal or purpose. In this respect Galliers' definition offers little more, over and above existing definitions, apart from acknowledging the component of conflict. Communication takes place on occasions, to numerous to categorize, where there is no common goal or purpose to achieve, nevertheless, the actual process of communication is deemed as being a cooperative venture and to have a purpose to some end (cf Grice, 1975). Even where states of severe conflict exist between agents and goals are very different, communication can still take place and the act of communicating, even to discuss differences of position, indicates cooperation.

What is taking place in these situations is an act of cooperation in communication - that is, maintenance of the communicative stance or state is a goal per se, in order to achieve more distant goals and objectives. Cooperation is a state that can operate on varying levels and ignoring this distinction causes confusion. I believe that Galliers has not made this distinction and confuses the nature of cooperation underlying the communicative process with the nature of cooperation required by agents either to achieve a common task or goal or to negotiate the resolution of conflict. Most of the definitions of cooperation include this concept of a 'common goal' without acknowledging that some activities are cooperative in essence.

The nature of cooperation involved in communication can be likened to the activity of a competitive game such as football or chess or a sport such as boxing. The participants need to have a level of cooperation to participate in the game regardless of their objectives for the outcome of the game, which individually are likely to be very different. A team of footballers have the objective of their side winning and the other side losing; likewise with a competitor in a game of chess or in a boxing match. One agent wants to win with the consequent loss to the opponent. Competitors in such activities are not working together to achieve a common purpose and if a draw results, both sides generally view such an outcome as disappointing and not in concordance with their original goals. Nevertheless, participants are cooperating to 'play the game'.

They abide by its rules and maxims otherwise it could be argued they are not playing the game in question.

I would argue that Galliers confuses the concept of cooperation with that of compliance and that this partly stems from her views of conflict and the roles that agents are given, of being able to 'manipulate' each other's knowledge configurations (ibid: 68; the term she uses is 'mental states'). As far as Galliers is concerned conflict has an important role in the maintenance and stability of cooperative multi-agent systems (Galliers, 1989: 67).

The view adopted in this thesis is different. What is being argued here is that the very nature of the human condition can be viewed in terms of conflict and that cooperation has evolved to deal with the conflict that is inherent in the interaction between human agents. Moreover, it is also argued that cooperation derives from self-interest (Axelrod, 1984: 6-7 & 2.1.3).

This is a very different emphasis than that of Galliers who proposes that conflict has a positive role in maintaining cooperation. Rather than viewing it from this angle, cooperation should be viewed as a means of diminishing conflict. It is by the establishment of cooperative processes that order is brought out of chaos and organization is achieved from agents pursuing disparate goals. Conflict is a characteristic of human affairs and it is either eliminated or diminished by negotiation, and to the extent that agents can mutually achieve their goals and aspirations.

Without processes of cooperation, interaction and communication can quickly slide towards a state of conflict. This does not mean to say agents will always achieve their goals. Some goals of other agents are accepted in preference to one's own goals because they are seen to be advantageous in some way or other. It is also inevitable that some goals might have to be dropped and the goals of other agents accepted, either voluntary or by imposition, because of the power relationships existing between agents and groups of agents within society.

The place of conflict in human interaction adopted in this work as opposed to that of Galliers', might be considered as a difference in emphasis but it is not only this.



Cooperation is a relationship between agents which is viewed as evolving out of conflictual relationships, that exist inherently between human agents. The communicative process above all must be viewed as a cooperative process by which agents can interact with one another and have a basis from which to negotiate other conflicts.

It is an assumption of this work that language and its major components - syntax, phonology and semantics, have evolved as a function of language and that a major characteristic of this functional use of language is to provide agents with the skills of a cooperative nature. A person has far more to gain from mutual cooperation in language than mutual defection, for if an agent cannot make herself understood her chances of achieving her goals is decreased, which has implications for survival.

Therefore, a definition of cooperation for this work is as follows. Participants involved in communicative interaction are engaged in a shared process. They work together and act in conjunction to the same end which is to maintain the communicative process until one or both of their purposes for doing so are considered achieved or to have failed. The practice of communication is viewed as being the most economic and advantageous way in which purposes and goals are achieved and existing conflict either avoided or diminished or even increased, if that is the agent's purpose.

#### **2.1.4 Assumption 4 - Conversation is characterised by regularities rather than rules or principles**

Many researchers describe conversation as being a highly organized level of language and emphasize the characteristics of structure (Atkinson & Heritage, 1984; Coulthard, 1977; Hinds, 1979; Hoey, 1983; Reichman, 1985). This structure and the way in which regularities occur in an orderly manner suggests to many researchers that conversational interaction must be governed by rules and that these rules must be tacitly known to all interlocutors (Chomsky, 1976; Labov & Fanshel, 1977; Schank, 1977).

The task to be confronted by the analyst is two-fold. Initially, the forms of the units from which conversation is constructed need to be identified and described and then the sequencing of these units and their occurrence need to be demonstrated. Furthermore, the analyst needs to know what underlying principles are shared by interactants for communication to result in a successful joint production. Different analysts have focussed upon varying characteristics and identified in these the units of language: e.g. the utterance, the sentence, the adjacency pair, the move or the speech act, along with theories as to how they might be sequentially connected. Each have their protagonists as being the structural units of conversation.

So widely assumed is the 'rules and units' approach, the assumption often remains unchallenged and the only questions that are asked are about the nature and type of rule believed to be governing the units of conversation.

Taylor & Cameron (1987: 8) are researchers who have raised some very pertinent objections to this approach. They argue that many researchers never question why particular rules are there in the first place or how the rules that are assumed to govern conversation come into being.

They draw a distinction between a 'rule' and a 'regularity' and ask whether it is the case that any discerned regularity in conversational interaction should be taken as evidence for the existence of a rule (ibid: 11). Within the social sciences it is acknowledged that more than just regularities are needed to justify the existence of a rule and that there needs to be some evidence that a prescription is being followed (Harre, 1974: 143). In the view of Taylor & Cameron:

"...mere regular behaviour in situations is insufficient to confirm the existence of a specific rule. It is always possible to formulate a number of rules according to which one's data make perfect sense; but it is very difficult to evaluate the alternatives in any sensible, let alone conclusive way" (ibid: 51).

They argue that many analysts who use the rules and units framework are unable to produce good evidence that a remark has in fact been heard as any particular category of act and that without this sort of evidence it is impossible to see whether one set of rules is any superior to another set. These criticisms complement the view presented in this work that certain regularities can be discerned as underlying conversation but that these are not necessarily rules or principles that have any apriori justification.

#### **2.1.5 Assumption 5 - conversation is intentional and plan-based behaviour.**

A premise of this thesis is that conversation is an instance of purposive, rational and intentional behaviour. People use language primarily to communicate with other people, in pursuit of their own goals. In this respect, a speaker's motivation plays an important role in structuring what she says. An assumption of this study is that language is action (Austin, 1962; Brown, 1980; Goldman, 1970; Searle, 1969). Also, that people think about what they say and in doing so formulate goals and plans by which these goals can be pursued and achieved.

Alvin Goldman in his book 'A Theory of Human Action' argues that purposive behaviour is closely connected with the concepts of 'reasons' and that 'reason type explanations' are a species of causal explanations for human behaviour (Goldman, 1970: 76). Anscombe defines an intentional act as one which the agent does 'for a reason' (Anscombe, 1957: 9). I do not intend to discuss the philosophical implication of what it means 'to do something for a reason' but to note that the notions of reasons and reasoning is intimately tied to that of intentionalistic states.

My aim in raising the matter here is to refer to Goldman's argument that acts are caused by 'wants' and 'beliefs' and that these concepts play a central role in the analysis of intentional action and in any explanation of action. Language can be viewed as an instance of goal-oriented behaviour motivated or 'caused' by the factors of

'wants' in the form of 'beliefs' and 'intentions'.<sup>1</sup> Utterances are produced in the form of speech actions and are executed in order to have some effect on the hearer. Action representations are not only or merely programs for doing something, they are also knowledge structures that may be used by other processes. The effect that a speaker intends to have on her hearer is that of modifying the hearer's beliefs or goals.

A central assumption of this study is that people are rational agents who are capable of forming and executing plans to achieve goals. This is in line with numerous recent studies (Allen, 1983, 1984; Allen & Koomen, 1983; Allen & Perrault, 1978, 1979, 1980; Brown, 1980; Galliers, 1989; Levin & Moore, 1977; Pollack, 1986). These studies, viewing language as intentional behaviour, provide tentative solutions to a wide range of linguistic problems at the sentence level and exploit the fact that language is primarily designed for the transmission of goals. Some of these studies have indicated, that identifying the goals of the speaker provides a natural way of dealing with sentence fragments such as noun phrase utterances, sentences that should not be interpreted literally but as indirect speech acts, and utterances whose purpose is to clarify, acknowledge or correct a previous utterance (Allen & Perrault, 1978,1980).

Relevant to the intentional and plan-based characteristic of conversation is the research relating to speech act theory (Austin, 1962; Searle, 1969, 1979); pragmatics (Grice 1975; Leech, 1983; Levinson, 1983); and planning (Bratman, 1983, 1987; Bruce, 1980; Bruce & Newman, 1978; Miller, Galanter & Pribram, 1960; Schank & Abelson, 1977; Wilensky, 1979, 1983). The subject of planning is discussed further in chapter three as this activity is considered to be a strategic element in the conversational process.

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<sup>1</sup>Further clarification of these ideas are made in chapter 3 in the discussion of Bratman's views concerning intention which are adopted for this work.

### **2.1.6 Assumption 6 - Conversation is inherently organized and structured**

An obvious but an initial point to be made is that conversation is a joint production. This implies that speakers constantly take account of their audience by designing their talk for their hearers. Not only might a speaker shift their style of language to suit the context but will have some idea of what their audience already knows and what they want to know. Therefore, they will have some idea how to select and present the information.

The structure of conversation relates to such questions as: How do conversations commence and how are they maintained or terminated? How are the conventions of turn-taking organized and distributed? How are topics chosen and introduced and how does focus and attention change? What place do repairs and false starts have in conversational organization and how are interruptions made, questions asked, and answers given or evaded? These are a few of the characteristics that affect the conversational flow and whether it is maintained or disrupted.

Schegloff & Sacks (1973) noticed that some turn-allocational techniques do set themselves more clearly apart such as an addressed question selecting its addressee to speak next, or that in starting to speak when not selected, a party selects herself to speak.

The former technique relates to one case of a class of utterance types, or 'types of sequences' parts, which share the property of possibly selecting next speaker. These class of sequences are characterized by the following features; (a) two-utterance length, (b) the component utterances appear in adjacent position, and (c) different speakers are responsible for producing each utterance (Tsui, 1989: 545). These sequential units are termed 'adjacency pairs' (Schegloff & Sacks, 1973: 295). The adjacency pair class of units also includes such sequences as greeting/greeting; invitation/acceptance or decline; complaint/denial; compliment/accepts or rejects; challenge/rejection; offer/accept or reject; instruct/receive; summons/answer

(Schegloff, 1968); openings (Schiffrin, 1977) closing sequences (Schegloff and Sacks, 1973).

The components and rules of Sack's turn-taking model for conversation define 'legal' points of transfer from one speaker to the next and conversation is said to develop in the manner of adjacency pairing. However, it is evident that the organization of conversation is not always made up of 'adjacency pairs' and this aspect of the ethnomethodological approach to conversational analysis has come in for some severe criticism (Brown & Yule, 1983; Ellis & Beattie, 1986; Reichman, 1985; Taylor & Cameron, 1987).

Whilst there are some sequences that have preferred or dispreferred second parts such as those identified above, not all conversation is of this type and there are stretches of conversation that cannot be characterized in this manner. As has been suggested, there are other options, such as the potential for a three-part exchange with an optional fourth or fifth part (Tsui, 1989: 562) and possibly others.

Reichman (1985: 174) argues that the adjacency pair approach to the structure of conversation is an insufficient model and does not explain or describe adequately the structure of conversation. This she sees as being because of its emphasis on paired forms and concludes that this emphasis makes it an analysis which restricts itself to a linear development of conversation only. Furthermore, she argues that it has no way of explaining that aspect of conversation that is nonlinear and non-sequential. She proposes an alternative model based on 'context spaces' and which attempts to model an episode of conversation in its entirety.

Her model seeks to explain the frequent shiftings, suspensions, and resumptions of topics that are characteristic of most conversations. She envisages conversation as a series of moves - e.g. 'support' and 'challenge' and her principle goal appears to be to make Grice's conversational maxims more amenable to computation. Her approach is more concerned with conversational moves as they relate to an argument or discussion and may be better viewed as conversational strategies (cf Stutt, 1989).

Reichman's ideas are not of great relevance to this work and I do not intend to discuss the structure of conversation in any depth. The reason why I have introduced the subject briefly here, is that an assumption underlying this work is that it is not possible to attribute structure to a conversation unless the beliefs, communicative goals, intentions and plans of the participants are known. Attempts have been made to categorise conversational structure, such as Reichman has done, but the difficulty with this approach is that different researchers categorise conversations differently and there is little agreement between them as to what the 'moves' or 'units' of conversational structure are.

The approach of this work is different. Conversation and dialogue are structured but this structure can only be ascertained as far as the beliefs, intentions, communicative goals and plans of the participants can be discovered or are revealed. It is acknowledged that there are even greater difficulties with this approach as participants to a dialogue or conversation rarely reveal their beliefs explicitly or their goals motivating their utterances and assessments by analysts can only be subjective at best. However, in the work presented here an attempt is made to model the beliefs, goals and plans of a number of agents in order to show how these result in certain utterances being made and goals achieved. The resulting conversation or dialogue has a structure but this structure is related to and reflects the communicative goals and beliefs of the participants.

What I now wish to discuss is some of the earlier computer implementations attempting to model dialogue which have been based on ideas relating to these assumptions and also to discuss and note some more recent research on the subject.

## **2.2 Models of dialogue and related research**

Efforts to program computers in an attempt to elucidate speaker's and hearer's, problems have led to some understanding of how the speaker decides what to say next, of how hearer's understand what is said, and of how conversations might be structured.

My purpose here is to review some of the work and programs that have been written and to offer some kind of critical review of systems that are models of dialogue. Immediately below I have briefly surveyed some of the language production models that have been reported in the literature. In this brief review I do not intend to discuss programs or models which focus on the organization or structure of dialogue above the single utterance; those approaches that rely on the notion of *focus*; or those that concern a particular aspect of dialogue, e.g., argument, conflict, narrative, etc., as these are not of immediate concern to this work (Carbonell, 1981; Galliers, 1989; Grosz, 1977, 1978, 1981; Hovy, 1988; Reichman, 1985; Stutt, 1989).

### **2.2.1 Early models**

Two dimensions appear to have characterised earlier attempts to model dialogue. Question-answering systems and programs which sought to emulate human conversation and language complexity.

Question-answering is a characteristic of language which presents as being a straight-forward context in which to experiment with the understanding and communicative ability of the computer. These consisted in experimenting with a store of information, or the mechanism for developing such a store and a procedure for extracting appropriate information from the store when presented with a question.

Some of these were BASEBALL (Green, Wolf, Chomsky & Laughery, 1963; STUDENT (Bobrow, 1968); SIR (Semantic Information Retrieval) system (Raphael, 1968). Whilst these programs are possibly the most commonly referred to in the literature (Boden, 1977: 96 and other places) the work in question-answering systems has been considerable and continues at the present time. Space does not permit each system to be noted and discussions of this early work can be found in Barr & Feigenbaum, (1981, 1982); Feigenbaum & Feldman (1963); McTear, (1987); Minsky, (1968).

The other major dimension of earlier research; programs that emulate human conversation have also been widely referred to and discussed within the literature.



These include ELIZA (Weizenbaum, 1966); PARRY (Colby, 1973); SHRDLU (Winograd, 1972); GUS (Genial Understander System) (Bobrow, Kaplan, Kay, Norman, Thompson and Winograd, 1977) and the Dialogue Games Model of Levin & Moore (1977) and Moore, Levin & Mann (1977). There are many other less popular models.

These early programs are of a special format type. The systems generally used two special formats designed for the particular subject matter they were dealing with. One of the formats was for representing the stored knowledge of the system while the other represented the meaning of the language input. Such an approach has its limitations and other researchers sought to design systems which were not limited by their construction to a specialized and particular context and used English text as a basis for storing information. I do not intend to discuss these models of text production here as the focus of this research is not on text production per se, but on the phenomenon of natural language dialogue. Some of these programs are: PROTEUS (Davey, 1978); ERMA (Clippinger, 1977); DEBBIE (Sedwell, 1985).

There are other systems which I do not intend to discuss as they are of limited interest relative to the considerations required for a model of natural language dialogue. Among which are Carbonell & Collins' (1973) SCHOLAR which produces an arbitrarily ordered list of sentences relating to geographical facts about a given country; Schank's (1975) SAM and Meehan's (1977) TALESPIN both of which are story generators based on Schank's (1972, and elsewhere) theory of conceptual dependency.<sup>2</sup> Related to these programs are PAM and QUALM. PAM (Wilensky, 1983) concerns the notions of plans, goals and themes in story comprehension and QUALM is a question-answering system which was used in conjunction with SAM and PAM (Lehnert, 1981: 149). None of these systems produce natural dialogue and therefore are not included in this brief survey.

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<sup>2</sup>These are discussed in, *Inside Computer Understanding: Five Programs Plus Minatures* by Roger C Schank & Christopher Riesbeck. Also included are discussions of Robert Wilensky's PAM and Jaime Carbonell's POLITICS programs

There is one program which requires to be examined in some detail and that is Power's (1974, 1979) model, the purpose of which was to model conversation directly. Although it is not a program that is discussed widely in the literature, it is one that comes closest in an attempt to model the relationship between the goals and beliefs of the participants and their utterances. Power's model and research is very pertinent to the present work and requires to be examined at some length.

### **2.2.2 Power's computer model of conversation**

The major objective of Power was not the structuring of individual utterances but the higher-level organization of dialogue. In this sense it is a 'performance' model of language rather than a 'competence' model in Chomskyan terms. If we are to understand a conversation, Power argues that at least three fundamental factors have to be accounted for. These are the goals of both speakers and the conversational conventions that both the participants to the conversation share (Power, 1974: 3). Without an acknowledgement of the place of these elements we are unlikely to discover how it is possible to conduct coherent, purposeful conversations.

Behind this thinking is the idea that a speaker, not only conveys meaning by the utterances she makes but is also trying to do something or to achieve some purpose. Also, the hearer has not fully understood an utterance in its entirety unless she has perceived its purpose as well as its literal meaning. What is being considered is that language is not only a medium for communicating information but used rather as a purposive instrument in achieving plans and goals. Power's program appears to come closer than any other, to having communicative purposes that change in the course of a conversation. Steedman & Johnson-Laird have drawn attention to the fact that it seems to be the only study in which two copies of a program have been used to model both participants in a dialogue and which is conducted entirely by themselves. (Steedman & Johnson-Laird, 1979: 125)

### **2.2.2.1 A brief description of the program**

The program is somewhat unique in that it seeks to model a conversation between two robots rather than a conversation that might take place between a program and its human operator. In constructing his model in this manner Power was influenced by previous language-producing programs in which the human operator interacted with the system. He makes the point that in these systems, it is the human operator who almost always takes the initiative and determines the overall structure of the dialogue. The problem about this is that the processes by which the operator takes the initiative and maintains the overall control over the conversation remain hidden in her mind and are not made explicit (ibid: i). The aim of Power's program is to make these processes totally explicit and therefore, human participation is avoided.

The two robots are each represented by a section of the program and the conversation between them is conducted in a small subset of English. It is a mixed-initiative dialogue which can involve interruptions and the nesting of one segment of dialogue within another. The robots are placed within a simple world of a few objects in which they co-operate to achieve a simple practical goal in this world. Their conversation is meant to arise naturally out of this common aim and each remark relates to the goal they are trying to achieve. The robots have to agree on a plan, exchange information, discuss the consequences of their actions and carry them out.

The program has two kinds of procedures called ROUTINES and GAMES. The GAMES are used to conduct sections of conversation while the ROUTINES mirror the underlying thoughts of the robots. There are several GAMES each of which correspond to a common conversational pattern such as a question and its answer, or a plan suggestion and its response to it. GAMES are joint procedures in which instructions are divided between the robots and determine what can be said, which robot will say what, and how each utterance will be analysed and responded to. When a section of dialogue occurs the relevant GAME is loaded in the minds of both robots but each adopt different roles and consequently, perform different instructions and produce different utterances.

The two sections of the program are controlled by a 'chairman' function which runs the conversation and which is initiated by the operator. The chairman first calls the section of the program representing John. John then thinks for a while and eventually returns control to the chairman. This usually occurs because he has just made an utterance and needs to give Mary a chance to reply. The chairman then calls Mary who in turn decides whether she wants to say something. Control alternates in this way between the two robots until the run is completed and neither robot has anything more to say. Before calling the chairman the operator needs to define the starting position by initialising key variables as to the state of the world, the names of the robots, what actions they can perform, what their beliefs are and what their goals are. An example of the dialogue that the program produces can be found in Appendix 8.

The way in which language is dealt with within the model is by way of an internal language. Expressions in this internal language are translated by specific functions into English and vice versa. Power admits that no attempt is made to do a proper parsing of the language used, or even to bother with grammar at all (ibid: 198, 202). The reason for this is that his purpose was not to model language per se but the structure of dialogue and therefore, to focus on parsing or grammar he saw as being non-essential to his main purpose.

Although routines and games are major control structures, they are not the highest level of control. These structures have to be interpreted and sometimes a decision has to be made to discontinue them in order to make an utterance or swap control to the other robot. The various parts of the program responsible for this come under the broad title of the 'Executive' (ibid: 187-197). There is a master function for each section of the program which represents the mental processes of each of the robots. The algorithm representing the mental processes forms part of the 'Chairman' program and when it arouses one of the robots it runs until it makes an utterance or swaps. Power admits that this is something of a problem but sees it as being a limitation characteristic of setting up a conversational system inside a computer which

is a serial system. It is impossible to have each of the robots thinking at the same time as would occur naturally with speaker and hearer.

The way in which Power has dealt with this problem is to use a time-sharing system so that the minds of the robots work in psuedo-parallel. In his program he has a short 'Chairman' procedure which calls the robots alternately (ibid: 188-189).

#### **2.2.2.2 Evaluation of Power's program**

Power has captured some important features that characterize natural language dialogue. The robots in Power's program can 'learn' within certain limitations. By perceiving certain changes in their world the robots have their memories updated. This is not done automatically as changes in the environment have to be noticed by the robots by an examination of the objects they can see. This is an important feature in natural language dialogue as participants need to remember at what stage they are in a conversation and be able to update their knowledge of what information has been supplied, what goal or subgoals have been achieved and what still needs to be said. Without such updating a person would not be able to carry on even the simplest of conversations and might ask the same question repeatedly although having already received the answer. This aspect is linked with another vital characteristic which is that each robot has a model of the world and also a model of its partner.

Power makes a distinction in the types of knowledge that the robots possess. Much of the knowledge that they have never changes during a run of the program. For example, knowledge about how to make plans, how to use language, what can be seen or done, how many objects there are in the world. This type of knowledge remains constant once it has been set by the operator whereas the knowledge of object positions can vary. Theories concerning the consequences of actions can change as can one robot's model of the other robot's mind. Plans, goals and utterances can also change.

Generally, the knowledge that the robots have can be divided into two main kinds: their model of the world and the model they have of the mind of their partner. Each of

the robot's model of the world holds their beliefs about the positions of objects, that is, the current state of the world, and their theories of how the world works, their beliefs about the consequences of actions. Their models of their partner's minds consist of what the other can or cannot see, what the other can do and what the other's beliefs are about how the world works. The robots use their models of the world and of each other's mind to construct and carry out their plans in achieving goals. In this respect Power attempts to deal with vital aspects of natural language dialogue.

Even so, the program cannot be said to include a model of the other participant beyond a few facts concerning their goals and basic abilities. It is the lack of an appropriate model which leads to the pointless exchange of utterances 8 to 13 (see Appendix 8). Steedman & Johnson-Laird (1979: 128) make the point that this exchange could have been avoided if Mary had known that people do not seek to achieve goals that are already attained, and had updated her model of John's mind accordingly.

#### **2.2.2.3 Problems and limitations of Power's program**

Power himself anticipates a number of criticisms of the model and identifies some of the defects of the program (*ibid*: 207). The conversational pattern is too rigid and John and Mary are too much alike. All sections of conversation have to be announced and there are no proper facilities for putting right misunderstandings. The robots are unable to detect violations of illocutionary rules, cannot refer to previous sections of the dialogue or tell whether or not a game is appropriate.

Power draws attention to a characteristic of the program which he describes as being its most important feature. This is that the conversation is divided into short sections, each of which is generated by a joint procedure. He draws attention to the fact that these sections contain two or more utterances but generally only two (*ibid*: 203). In a later article (1979: 111), he indicates that the program is based on a view of conversational structure which resembles that of Schegloff & Sacks (1973) which consists largely of the 'adjacency pair' (2.1.6). Though no mention of the adjacency

pair is included in the original discussion, Power suggests in this later paper that there are strong grounds for considering the adjacency pair to be a more important unit of conversation than the utterance. Furthermore, he states that the program implements these ideas in that the robots have a list of instructions which lays down how each utterance in the pair should be produced and interpreted.

It has been previously noted that there are doubts as to whether it is possible to give the 'adjacency pair' the sort of pre-eminence that some researchers do, as a great deal of conversation does not follow the structure of the adjacency pair. As a unit of conversational structure it is only able to explain some of the phenomena that occurs in dialogue (2.1.6).

What is significant about Power's later work is that while he notes the ethnomethodologists work in relation to the adjacency pair, he makes no mention of Sack's model of the turn-taking mechanism (2.1.6 & Appendix 7). It is this aspect of turn-taking between the robots in his program which constitutes one of its major weaknesses. It has been previously noted that the robots alternate under the control of a "Chairman" function which initially calls the robots by name. The calling of the robots by name each time is both unnatural and contributes to the dialogue becoming long-winded and repetitive. As a consequence, Mary and John are not communicating directly but through a third 'party'. Rigid alternating between the robots is unnatural and somewhat artificial.

At no point in Power's model can the current speaker decide to continue the conversation as she could in a natural dialogue and which is allowed for in Sack's turn-taking model. The speaker is regulated strictly by a device somewhat removed from both robots. The robots do not respond to the second part of an adjacency pair because of any inference that can be made about the first part which requires such a response (Power seems to imply this in relating his model to the adjacency pair), but because the 'Chairman' calls them to do so. An appropriate model of dialogue will have to address this problem and find a way so that what is said by one speaker elicits a response without the aid of some external device. Such a response needs to arise

from the models each speaker has of the other and from the model of the conversation so far developed.

Another weakness of the model is that the robots are not able to recognise the plans or the goals of the other without them being explicitly announced (ibid: 209). It has been noted that speakers and hearers make sense of much language phenomena by being able to infer the goals and to recognise the plans of the other participant (2.1.5). Power admits that his robots cannot infer the other's intentions and that this was done for ease of design and clarity. Nevertheless, it is a feature which appears to be integral to understanding in dialogue and any model which ignores this characteristic is likely to be deficient.

For each type of conversation in the program there is only one game definition (ibid: 207). This means that the dialogue takes the same pattern each time. Apart from the call of the other's name, every other utterance is expected, in the sense that the hearer knows in advance which move it is in the game. Power suggests that the kind of rigidity exhibited by the program is an inevitable result of using games, since the whole idea of a game is that the robots are following a procedure with a fixed definition which they both know in advance. The method depends on both robots having exactly equivalent game definitions and being able to agree about the position reached at any point in the game. Consequently, the robots never have misunderstandings with each other whilst in the process of a game, which is not a characteristic of natural conversations. If the robot is linked to a human operator (which it is possible to do) there are continual misunderstandings if the operator is unable to follow the game definitions implicitly (ibid: 208).

The fact that all sections of conversation have to be announced is a further objection that is linked with the first two (ibid: 209). Every time an ordinary game is played, it first has to be announced by a special function. It is designed in this manner so as to bring the control structures of the robots into line with each other to make sure they have the same game loaded. Power admits that this is one of the most unnatural features of the conversation and that the program could be adapted so that extensive



use of this was unnecessary. Though some adaptation might be possible, the problem remains in essence because of the method employed and therefore is a major defect.

The robots have no proper facilities for putting right misunderstandings (ibid: 210). If a remark by a partner cannot be interpreted there is only one possible response. The robot has to call her partner to get GAME loaded, declare that a muddle has arisen which cancels all routines except BASIC and start afresh. Consequently, the robots start again at an earlier point in the computation whereas the misunderstanding could have been a minor one which did not warrant going so far back.

Human language-users are extremely competent at conducting meta-conversations to retrieve previous conversations. The robots cannot do this because they lack an understanding of what each of the games are meant to achieve nor do they know why the instructions making up each game are suitable for achieving the game's purpose. Furthermore, the robots lack an understanding of what the language they are using is meant to achieve. In a natural conversation, if something is not understood it can either be by-passed, in the expectation that something later will clarify what has been said, or a hearer can inform the speaker that they do not understand or ask for clarification. In this respect language is used to put right the misunderstanding that has occurred. If the robots were given more effective models of their partners and were able to recognise the plans and goals of the other as well as their own, in the actual language being used, they would have a better facility for putting right misunderstandings.

Finally, the robots are unable to refer to previous sections of the dialogue (ibid: 203). This is because the utterances are the entries in the games and which are local variables of joint procedures. As soon as the game exits these variables are lost. The robots do not have a model of the conversation as it develops so are unable to answer any questions relating to previous sections of the dialogue nor can they make comments about it. In the part of the dialogue given as an example in Appendix 8, John announces to Mary at 7 "Shall we make a plan", Mary, unable to detect violations of illocutionary rules ( John's request to get in, 5) interrupts John by asking him whether he is already in [12]. After receiving his reply in the negative she announces at

14, "Shall we make a plan" a suggestion made by John only six short utterances back. Power admits that this part of the system is impossible to adapt in order that reference be made to previous sections of the dialogue. This is a major weakness and one that any model of dialogue needs to overcome.

Power's work is valuable in relation to this research and serves as something of a landmark in attempting to model conversation. This present work complements some of his ideas which are considered important such as the motivating factors of beliefs, goals and plans in conversation. He explores the nature of conversation in relation to its organisation and structure which can be viewed as being a most useful direction to pursue and is another aspect related to this work as far as structure and organisation relates to the original beliefs and goals of the participants.

His is a model that builds on speech act theory and emphasises pragmatic aspects of dialogue such as performance and context. His model also attempts to tackle conversation from the perspective of some of the major assumptions which have been identified in the first part of this chapter such as purposive and cooperative behaviour as well as planning to achieve goals. Also, to model these from the viewpoint of both participants simultaneously.

The model is not without defects as have been identified but his work has had a major influence on the ideas presented in this thesis.

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### **Chapter 3 - A theory of rational action and interaction as a basis for a theory of purposive dialogue**

The main idea motivating this work considers dialogue to arise from the interaction of the participants' beliefs, knowledge and intentions, in the pursuit of plans and goals. These give rise to communicative goals which are realized by the participants making choices from specific semantic options relating to the social context of the speech situation which in turn, are realized in speech actions that utilize specific grammatical/vocabulary options (Halliday, 1973, 1978).

The foregoing might be seen as a statement of the obvious but while we might believe dialogue is produced in this manner it is a different matter to make these processes explicit. It might be the case that we understand the utterances speakers make by making all sorts of inferences about the speaker's intentions, knowledge and beliefs but it is not possible to examine the specific beliefs, knowledge structures and intentions of an agent that motivated a particular utterance. This is for the simple and self evident reason that we do not have access to another person's mind.

Consequently, much of the research into conversation, analyses dialogues or dialogue-texts after the event. The purpose of this being to ascertain the structure of the dialogue in an attempt to define or describe the motivations, strategies and intentions of the speaker and by this method to arrive at an understanding of what is going on between a particular speaker and hearer. The difficulty with this method of analysis is that it remains a subjective assessment of what is actually happening and different analysts might come up with differing conclusions about a particular piece of dialogue.

This work approaches the problem from an altogether different direction and by constructing a model of two or more imaginary agents each with a set of communicative goals. These agents are provided with a set of beliefs some of which are individual beliefs, while some others are held in common. Each agent is also given a particular goal they need to achieve. Goals are achieved by the agents pursuing individual plans which involve them displaying utterances to the other agent. Each

agent is provided with knowledge structures as to the type of utterance to be displayed. The purpose behind this enterprise is to make the processes of dialogue explicit.

Underlying such a model is a theory of interaction which is rational and which is a basis adopted by many researchers and theorists (Cohen, 1984; Cohen & Levesque, 1987; Galliers, 1989). It appears to be the view predominating within the literature and the purpose of this chapter is to describe the characteristics of rational agents and rational action that form a basis for this model of dialogue.

What I propose to do in this chapter is not only to describe the characteristics of rational agents but to explain how these characteristics fit into the model of dialogue as presented in this work.

### **3.1 Characteristics of rational agents**

#### **3.1.1 Rationality**

An assumption of this research is that dialogue is a cooperative enterprise (following Grice, 1975) and that this characteristic of cooperation derives from the underlying rationality of the participants. Another assumption is that human beings are planning agents and that the plans they create are used to achieve purposes and obtain goals and objectives. Human beings are able to make and to be committed to plans because their actions derive from knowledge about themselves and of the world in which they are situated with other agents. This knowledge consists of beliefs and attitudes and the behaviour of human agents is motivated by these along with wants, desires and obligations.

A theory of rational action and interaction presupposes certain principles. These are that agents require a body of knowledge of how to perform their goals and that they do so with the knowledge that other agents operate in a similar manner. Agents have beliefs about other's intentions and goals and are able to reason about these in order to formulate their own goals and plans of how to influence the beliefs and goals of

others. Also, having beliefs about the beliefs and goals of other agents can affect one's own beliefs and goals.

There are differing views as to the nature of rationality. Davidson (1963: 700) adopts a 'holistic' perspective in which he views complete sets of beliefs and desires as inevitably fitting together rationally and sees all behaviour as being rational. Galliers (1989: 50) notes this descriptive approach in her work but adopts an evaluative approach to rationality in which actions are selected as rational in contrast to others, being dependent on relationships of consistency with the individual's other existing knowledge configurations. Another perspective is that of Ellis (1979) who argues that:

"the laws governing the structure and dynamics of rational belief systems are the laws of logic" (Ellis, 1979: vii).

He proposes a physical ideal of a rational belief system which has as a central component, the ideal of rational equilibrium. The concept is likened to that of a perfectly balanced ecological system.

"An ideally rational belief system is one which is in equilibrium under the most acute pressures of internal criticism and discussion" (Ellis, 1979: 4).

He acknowledges that such states may never be realized in actual systems but argues that the concepts used for an ideal system are useful for explaining the properties and structural features of ordinary human belief systems. Ellis makes the observation that ordinary human belief systems normally, and perhaps always, fail to be ideally rational for the reasons that they are being continually disturbed by new material (acquired beliefs) which are not or not always subjected to internal criticism and discussion. Even if acquired beliefs are subjected to this sort of examination the implications might not be always understood in order to be effective.

The approach adopted here follows that of Galliers (1989) and the ideas of Allwood (1976) which Galliers discusses at some length. Allwood's approach is also evaluative, relating rational action to the idea of consistency with the agent's beliefs and goals but with reference to some kind of independent assessment of those beliefs or goals. Allwood makes a similar distinction to that of Ellis:

"We are not making the claim that agents act rationally, but only the weaker claim that agents act in a way that seems rational to themselves (Allwood, 1976: 23).

Dennett (1978: 11) argues in a similar vein to Ellis that if an intentional system was perfectly rational all logical truths would appear among its beliefs. He acknowledges though, that any intentional system will be imperfect and so it is not possible for all logical truths to be ascribed as beliefs to such a system. Human intentional systems are imperfect for the reasons given by Ellis and thus Allwood's claim that agents act in a way that seems rational to themselves seems the more accurate and realistic proposition.

The assumption adopted in this research is that human beings are 'intentional systems' which implies that such systems are 'rational'. What this means is that if a person has p, q, and r, beliefs, it is supposed that this person believes what follows from p, q, and r. Without such an assumption we cannot make predictions or rule out that the person in question will not do something utterly stupid despite their beliefs. Our common sense explanations and predictions of human behaviour is that it is intentional and rationality is assumed. If an acquaintance produces an irrational response to something we say or do, our immediate reaction is not normally to question their rationality but to look for some other explanation. Perhaps they didn't hear properly what was said or perhaps they didn't understand. So entrenched is the presumption of rationality that our predictions of what is happening infer other explanations for the problems in understanding or breakdown in communication.

Because we view ourselves as acting rationally we assume that other agents act as we do. Dennett has suggested that:

".....one cannot have a world view of any sort without having beliefs, and one could not have beliefs without having intentions, and having intentions requires that one view oneself, at least, intentionally, as a rational agent" (Dennett, 1978: 253).

The logic of Dennett's statement forms the basis of rationality assumed for this work. Human beings are viewed as rational agents, but as has been noted, human systems of rationality are imperfect. Consequently, it is not possible for all logical truths to be ascribed as beliefs to such a system and therefore it seems unwise to attempt to construct such systems from which to extrapolate the psychological plausibility of particular processes.

It is not my intention to construct a model of rationality, perfect or imperfect, but to single out some aspects of a rational system that might contribute to the process of dialogue. The elements and processes singled out for emphasis in this model must be seen as belonging to a much larger rational system which is not modelled but assumed. These elements are goals, plans and sets of beliefs of two or more agents conversing together. It is assumed that these elements exist and function within a more complex rational system and it is against this background the model must be viewed.

What is now required is to identify the other components belonging to rational agents, those of intentions, plans and goals which stem from agents' belief systems and show how these particular elements relate to the model presented in this work.

### **3.1.2 Intentions and intentionality**

Intentions and intentionality need to be examined in the context of a theory of action and of practical reasoning from which they are derived (Anscombe, 1963; Davidson, 1963; Davis, 1979; Searle, 1980).

It has been previously noted (2.1.5) that a common approach to a theory of action is that actions are caused by beliefs, wants and desires but if this is the case we are left wondering as to what role intentions play. On the surface it would appear that actions are caused by intentions. Agents may adopt beliefs and goals to change others' knowledge configurations in order to effect changes in the world but in doing so they have intentions and these are intentions to act in specific ways.

Intentions appear to differ from beliefs in that the content of an intention is an action whereas the content of a belief may be a proposition or a psychological state (Engel, 1984: 51). Many studies of intention make attempts at reducing the concept to a combination of beliefs and desires but Bratman (1987: 14) argues that an intention must be considered a psychological entity in its own right.

Cohen & Levesque (1987) also claim that rational behaviour cannot be analyzed in terms of beliefs and desires alone and that the intentional component, though intimately related to these entities is not reducible to them but must be viewed as being an important component in its own right. This research adopts a similar view and more particularly the idea proposed by Bratman (1987: 28) that intentions are the sub-components of plans. This will be discussed further under the section on plans and planning.

The question arises as to what intentions actually are. They are most certainly 'inner events' but this tells us very little and the more closely intentional action is examined it comes to appear that intentions are dispositions of some complexity. Bratman (1987: 8) suggests that intentions can be viewed as sub-components of plans and this is a view that is supported by other observations.

Intentions and intentional states have objects (Meiland, 1970: 16; Searle, 1980: 48). Intentions are directed at or are about objects or states of affairs in the world. Meiland views the object of an intention as what is being intended or what the intention is about. If for example x has an intention to go to London and another intention to go to Milton Keynes, these intentions have different objects. One relates to the action of going to London and the other to Milton Keynes.



Objects of intentions and intentional states can be beliefs, desires, other intentions etc. Meiland (ibid: 16) makes a useful distinction which is that intentions can be conditional or unconditional and that the two types of intentions take different types of objects. Unconditional intentions have actions as their object while conditional intentions have objects which are actions that are performed in certain circumstances or under certain conditions. Conditional intentions have the form 'X will do A if C obtains'. The object of the intention contains a condition which is part of what the intention is about. Unconditional intentions are directed at an action object which has the form 'X will do A'.

Some intentions are intentions to perform certain actions as a means to some end; a way by which a more major goal may be achieved. An agent can have a certain purpose in carrying out some action but this is different from her doing some action for a purpose. Some actions are done as a means to achieve other purposes. For example, if X has an intention to save £100 by Christmas X must have performed certain actions by means of which X was in possession of the £100 at Christmas.

I do not propose to deal with intention and intentionality in any more depth as the subject is quite vast and the enquiry properly belongs to philosophy (Davis, 1979; Dennett, 1978; Meiland, 1970; Searle, 1980). The purpose in dealing with it here, albeit briefly, is to acknowledge this component of rational agents and its relationship to the elements of beliefs, plans and goals which are the elements with which this research is most concerned with.

In this work intentions are characterised as sub-components of plans. Sub-components of an agent's plan are realised in particular communicative goals which are related to specific utterances. Utterances between two agents form a dialogue, the structure of which reflects the wider and larger intention and plan of each agent which is composed of the smaller sub-components. By characterising intentions in this manner it is suggested that 'having a plan' and 'having a goal' are subjective states which when put into operation become intentional actions.

In the model of dialogue presented here each utterance that is made is directed at achieving some communicative goal which contributes to an overall goal of the agent. Therefore each utterance is categorised as being an intentional action which is a sub-component of a much larger intentional strategy and plan.

The concept of plan and planning now needs to be examined and an indication given of how the concept of planning is to be used in this work.

### **3.1.3 Planning - a framework for the organization of behaviour**

One of the assumptions stated in chapter two was that the nature and function of natural language was plan-based (2.1.5). That is, that language is an instance of purposive behaviour which is used primarily to communicate with other people in pursuit of goals. This assumption is based on the belief that language is action following Austin (1962); Goldman (1970); Brown (1980); Searle (1969) and others. Fundamental to this belief is that people think about what they say and in doing so formulate plans by which their goals can be pursued and achieved.

A distinction often made in relation to knowledge is that of 'knowing about something' and 'knowing how to do something'. Planning comes within the domain of the latter, and therefore can be viewed as an ability rather than as a static knowledge structure. Even so, the demarcation is not as clear as this as it is likely that plans often become knowledge structures in themselves and are stored in memory as such.

Research into planning and problem-solving has been one of the most energetic areas in cognitive science and in the area of artificial intelligence in particular. Miller, Galanter & Pribram (1960) acknowledge much of their thinking on plans as stemming from Newell, Shaw & Simon (1958). Others who have done work in this area are Fikes & Nilsson, (1971); Newell & Simon, (1972); Sacerdoti, (1975, 1977); Sussman, (1975); Tate, (1975). Much of this work relates to single agents performing physical actions in simplified domains, such as the manipulation of blocks on a table. More recently, there have been efforts to apply planning models to problems of discourse (Appelt, 1985; Hovy, 1988).

Generally, there has been three approaches in tackling this problem. Firstly, there are the approaches to dialogues concerning plan-based activities such as Grosz's (1977) work on dialogues between experts and apprentices involved in the task of repairing an appliance. A second approach is the use of planning models to determine the goals and plans of characters in a story. Among those who have worked on this approach are Bruce, (1980); Bruce & Newman (1978); de Beaugrande (1980); Schank & Abelson (1977); Wilensky (1979,1983). The third trend is that of planning in discourse and an examination of what is involved in the planning that must be carried out in the production of sentences and conversation (Appelt, 1985; Hovy, 1988).

### **3.1.3.1 Plans - what they are and why we bother with them**

When Miller et al., refer to a plan they refer to a hierarchical process in the agent that can control the order in which a sequence of operations is to be performed (1960:16). Bratman (1983: 271) suggests that when we refer to plans we can mean either of two things, distinguished by Pollack (1986) as either data-structures or mental phenomena. He suggests that a more careful usage of the terminology would reserve the use of 'plan' for the former and 'having a plan' for the latter (ibid: 271). Pollack (1986: 207) suggests that 'having a plan' is analysed as having a particular configuration of beliefs and intentions. This is the use that Bratman adopts which views 'having a plan' as being a state of mind, a use which I adopt in this work.

Thus plans are in the same category as intentions and beliefs but which are different as will be discussed later. A synthesis of the views of Miller et al., and Bratman, suggests that 'having a plan' is the state of mind whereby a person controls the order in which a set of beliefs and intentions are executed to perform a sequence of operations to achieve a goal.

Bratman (1983, 1987, 1990) is a researcher, who more than most others, has worked out in greater detail what sort of things plans are. His ideas harmonize with the views presented in this work and therefore are discussed in some detail.

### 3.1.3.2 Bratman's view of plans

Starting from the point that 'having a plan' is a state of mind, a plan can be identified as a coherent collection of acts a person can accomplish to achieve some end state. It can consist of one or more immediately executable steps or any step can be a plan in itself. Each plan has possible pre- and post- conditions, and as each step can be a plan, each step has pre- and post- conclusions.

Bratman (1987: 5-7), links plans and intentions closely together which is useful for my purposes. He claims that the approach to intention from a traditional philosophy of mind can be cited in terms of four theses (Anscombe, 1963; Goldman, 1970).

1. The methodological priority of intention in action.
2. The desire-belief theory of intention in action.
3. The strategy of extension.
4. A reduction of future-directed intention to appropriate desires and beliefs.

Briefly, what this strategy implies, is the idea that what makes it true for an action to be performed intentionally or with a certain intention, are those facts relating to the action as to what the agent desires and believes. 2 follows from 1 and the combination of 2 and 3 lead on to 4. Within this theory of intention, action is viewed as being a matter which is related to the agent's desires and beliefs, while intention to act is to be identified with some desire-belief complex. The rationality of intentional action in this view is primarily a function of the agent's desire-belief reasons for action. Other considerations bear on the rationality of conduct only indirectly and dependent on their relation to the agent's desires and beliefs. Bratman believes that all four theses should be rejected and thus also, the desire-belief model.

The problem he sees with these four theses is that they are more appropriate to an understanding of nonhuman animals but not to planning agents such as humans. Two

dimensions to the commitment of future directed intention are volition and reasoning. A characteristic of plans is that they are formed, retained, combined and constrained by other plans. Often they are only partial and need to be filled in, reconsidered and modified and the strategies expressed by the theses 1 and 3 do not do justice to the argument that humans are rational planning agents who have resource limitations and need to coordinate their actions both on an intrapersonal level as well as a social level.

Intentions can be viewed as the building blocks of plans and Bratman suggests that, "plans are intentions writ large" (ibid, 1987: 8; cf. Miller et al., 1960: 65). This is a useful way of viewing intentions and all things considered, it seems appropriate to reject the desire-belief model of intention in favour of a planning approach to intention. In this view intentions concerning future actions become elements in larger plans and so prior deliberation shapes later conduct. Prior intentions and plans provide a practical reasoning framework by which the desire-belief reasons for various options can be weighed. Such a reasoning framework provides a filter on options that become a potential solution to problems.

The ideas of Bratman accord with the basis of this work that communication is a rational, purposive activity. Intentions are somewhat intangible concepts but to cast them as components of plans make them more manageable. Utterances in this model are viewed as intentional actions following Searle (1980: 52) and therefore are seen as sub-components of higher-order plans in the achievement of speaker's goals.

There are other characteristics of plans which I do not intend to discuss such as control, stability, means-end coherency, and the hierarchical as well as linear nature of plans. Though these aspects are important as well as being interesting they are not relevant to my main argument which is the plan-based nature of dialogue that characterises utterances as being the sub-components of higher-order communicative plans and goals. Whereas many other studies have applied planning approaches to the higher-order and over-arching planning behaviour of agents this work applies it to agents' communicative goals and seeks to show how these might be made explicit in individual utterances.

### **3.1.4 Knowledge and belief**

Our day to day interaction appears to require that we have an internal model of the world on which to base our actions. To enable us to cope with the demands of daily living it is necessary for us to carry around in our heads a vast array of knowledge and information. Each of our cognitive functions - perception, memory, problem-solving and the use and understanding of language relies on this store of knowledge. A central issue for psychologists is the structure and content of this internal model and the restrictions and processes which govern it.

Models of perception, memory, problem-solving, and language understanding or production are dependent, to varying degrees, on the type of information structures they employ. If we were able to determine the structure and content of a person's internal model then psychologists could use this knowledge to extrapolate to other models, aspects of human behaviour. The way in which these internal models may be structured and organized has implications for models of other types of behaviour which utilize stored information.

Cognitive models of the mind or information processing models of memory display three basic characteristics:

1. The first concerns and relates to the structure of knowledge and how this stored information is represented within the memory system.
2. The second aspect concerns the nature of the processes which operate on this stored information and,
3. thirdly, the overall system structure which is the permanent and neural physical processing feature of the system.

My immediate concern is how the characteristics implied in 1 and 2 relate to this work. That is, how the knowledge or the beliefs of the agents are to be made explicit

and represented in this model and what might be the nature of some of the processes that operate on stored information in the process of dialogue.

Within the literature several different representational types can be identified and it becomes apparent that different types serve differing purposes and functions (Anderson, 1983: 76; Fodor, 1975: 194; Johnson-Laird, 1983: 157). It would seem that there exists a hierarchy of such types and even hierarchies within a type. It is the nature of this organization that contributes to the richness and flexibility of the system. Representations can be mixed and although at one level a psychological process may use a symbolic string of symbols, it may at a higher level use various sorts of representation such as images, mental models or propositions.

It is not my intention to deal with the subject of knowledge representation or the structure of knowledge at any length apart from how it relates to and affects this work.

The beliefs of the agents in this model are represented in a propositional form and it is this form of representation which is discussed in more detail. This does not imply that other representations such as spatial images (Anderson, 1983: 52), mental models (Johnson-Laird, 1983) and temporal strings (Anderson, 1983: 57; Pylyshyn, 1973: 2; Johnson-Laird, 1983: 146/148) are unimportant but rather that they are not viewed as being as amenable or as flexible as a propositional representation for my purposes.

Neither am I dealing with the structure of beliefs and knowledge and therefore do not intend to discuss theories of knowledge structure such as semantic networks (Quillian, 1968) or semantic field theories (Findler, 1979: see also Brachman & Levesque, 1985; Schubert, 1976) or frames (Minsky, 1975). Scripts (Schank & Abelson, 1977) are another form of knowledge structure and have some similarities to plan-methods that are used by this model. The way in which this concept is used will be explained in the description of the components of the model while a much fuller description of Schank & Abelson's ideas can be found in Appendix 5.

I turn now to a discussion of propositional representations of beliefs and knowledge which is the representation chosen for this work.

### 3.1.4.1 Abstract propositional representations

This approach to representation assumes that what a person knows can be represented by a finite list of propositions or axioms. Johnson-Laird (1983) uses the concept in its traditional philosophical terminology and states that a propositional representation is a mental representation of a verbally expressible proposition (ibid: 155). He reminds the reader that philosophers have generally taken propositions to be the conscious objects of thought - entities that we entertain, believe, think about and which are expressed in sentences and utterances.

These propositions are abstract constructs and not to be thought of as being tokens of actual sentences of some natural language that are being stored. Rules of deductive reasoning or some method of inferencing can then be applied to this list of propositions to generate all the logically valid propositions which follow from the initial premises. It is an approach which is generative in the sense that an unlimited number of 'beliefs' can be deduced from the initial representation.

This encoding process is more abstract in form than that of temporal strings or spatial images in that the code is independent of the order of information. For example, MARY SCOLDED JANE has the propositional representation of [scolded Mary Jane]. It encodes the fact that the two arguments, Mary and Jane, are in an abstract relation of scolding. The representation does not encode who is on the right or on the left of the example; that is, it does not encode the difference between MARY SCOLDED JANE and JANE WAS SCOLDED BY MARY. The encoding of the scene may ignore all other details such as the clothing of the participants or their spatial configuration at the time. What propositional encodings do is to identify certain elements as being critical and ignore all others.

Another feature of propositions is that they represent relational categorisations of experience. In development, the mind has learned to see certain configurations only which implies that there are constraints among the elements of propositions. For example, 'scolded' takes two arguments while 'give' takes three and 'decide' requires as one of its arguments an embedded proposition. A pertinent property of propositions



is their ability to detect elements that are connected before detecting how. The relational structure imposes conditions on propositional structure in that the relation only takes a fixed number of slots, no more and no less.

Sometimes, a relation is constructed in which not all the arguments are specified but even then we fill in the missing arguments by drawing inferences. For example, if we hear the statement JOHN WAS SHOT we cannot but help fill in the dummy agent; that is, the person doing the shooting. The notion of a missing slot is another feature in which propositions differ either from strings or images. It would be difficult to envisage strings or images having 'holes' in them. Strings and images appear to code stimuli directly and any combination is logically possible but individual elements of the string or image do not constrain what the other elements might be. Propositions do not reflect environmental structures directly but rather reflect an abstraction of the event.

The distinctive properties belonging to propositions derive from their abstract and set-like character (Anderson, 1983: 75/6). The encoding processes have to be learned. People learn from experience which aspects of an event are significant and accordingly develop a code to represent these higher-order properties. Such a process is a more direct and efficient way of storing information than the storage of raw stimuli data and is likely to yield an economy of storage in long-term memory.

Rather than storing sentences or the exact words of a sentence, the code represents the significant relationships between semantic components directly. Anderson (*ibid.*) points to other more significant advantages of such a representation. They will occupy less space in working memory and therefore, will not burden the pattern matching processes with unnecessary detail. Furthermore, the inferential rules or processes required to manipulate the structures, can be stored only for the abstract relations and need not be separately stored for all types of input that give rise to the relation (*ibid.*).

There is much empirical evidence to support this view of propositional representations and one of the principle lines of research comes from the various sentence memory studies (Kintsch, 1974: 150-151). These show that memory performance can be better predicted by semantic variables than by the word structure

or grammatical syntax of the original sentences. This research shows that the gist of what is said is recorded better than the memory for the exact words spoken or read (cf Bransford, Barclay & Franks, 1972).

Pylyshyn (1973: 12) and Anderson & Bower (1973: 151-156) have argued that a propositional code is sufficient to encode all kinds of information. However, Anderson (1983: 45) in his ACT\* system notes that for all the arguments for the sufficiency of propositions, they often prove quite cumbersome in implementation. He discovered that nonpropositional representations could work well in a production system framework. As a result, he argues that what is important is what can be done with a representation and not simply its form or notation.

Consequently, he argues for a tri-code theory of knowledge representation on the grounds that different representations are needed, not just for different applications but for different aspects of the same application. As an example he cites the generation of geometry proofs in which a linear structure is required to represent the order of statements in a proof; spatial structures to represent the diagram; and propositional structures to represent the logical interpretations of postulates (1983: 45).

Another discovery of Anderson which militates against the arguments for a propositional system over a multicode system is that the propositional representation of sentence word order can be complex relative to the simplicity of the string to be represented. This is because the conventions used in propositional representation are required for representing the complexities of other knowledge structures which means that characteristics pertinent to simple knowledge structures cannot always be capitalized on. Inefficiency results when processes have to operate on unnecessary detail.

From the foregoing it could be easily assumed that the concepts 'proposition' and 'propositional attitudes' are clearly categorised within the literature and without controversy. Unhappily, this is not the case and the concepts prove to be more slippery than this discussion would indicate. Barwise & Perry (1983: 177) draw attention to the differences that exist in defining the terms and suggest that there is little

semblance of any consensus as to what a proposition actually is. They point out that it has been categorised variously as: a state-of-affairs, sentence, sentence-meaning, mental representation, or a set of possible worlds. Nevertheless, though the formal definition of these concepts is not without difficulty the various senses point in a certain direction and it is these senses that we have to work with.

#### **3.1.4.2 The representation of knowledge in this work**

Knowledge belonging to the agents in this model has been characterised as their beliefs. These are represented as propositions.

Belief appears to have several components to it. A cognitive or knowledge component as well as an affective and behavioural component. It is not my intention to discuss the affective or behavioural components of belief in this work as the concepts associated with these components, though important, do not have any immediate bearing on my main objective. The cognitive component of belief is my immediate concern and it is this element which is represented in this work in a propositional form.

A distinction is often made in the psychological literature between beliefs as propositional attitudes and beliefs as psychological states. For example, Engel suggests that we should not confuse having a belief with being conscious of the contents of the belief (Engel, 1984: 53; cf Jacob, 1984: 72). It is not easy to unravel the distinction between the possible causal role of beliefs and their content and what is accepted here is the 'common sense psychology' notion that there are elements of both.

Jacob (1984: 69) points out that in our explanations of behaviour we typically invoke two kinds of mental elements, those of beliefs and desires and by combining them, make sense of behaviour. We say that Bill did such and such because he believed that *p* and wanted *q* and in doing so indicate that Bill has a certain preference for a certain state of affairs to pertain and chooses an action to realize this state of affairs. People are viewed as performing actions on the basis of having certain beliefs

which implies that psychological belief-states play a causal role in action (Galliers, 1989: 29). Both Engel and Jacob suggest and discuss different theories to this problem but which need not concern us further here.

Not all beliefs are equally important to the individual but by what criteria can a person's beliefs be distinguished as being central and important from those which are less so? The centrality of beliefs and the role they serve for the person has implications for that person's behaviour but some beliefs will have a more prominent role than others. Rokeach (1968) proposes a defining attribute of importance for beliefs which is in terms of 'connectedness':

"....the more a given belief is functionally connected or in communication with other beliefs, the more implications and consequences it has for the other beliefs and, therefore, the more central the belief" (Rokeach, 1968: 5).

This attribute of connectedness is used by Rokeach to order beliefs along a central-peripheral dimension. What arises from this ordering is the suggestion that the more central a belief is, the more it will resist change and the more the central belief does change, the more widespread the repercussions will be on the rest of the system. The four defining assumptions of connectedness are: (1) existential versus nonexistential beliefs; (2) shared versus unshared beliefs about existence and self-identity; (3) derived versus underived beliefs; and (4), beliefs concerning matters of taste (Rokeach, 1968: 5-6).

From these criteria it can be argued that the most central beliefs are those that are learned by direct encounter with the object of the belief. Such beliefs can be viewed as being incontrovertible as they rarely pose as being subjects of controversy, e.g. humans need air to breathe, death is inevitable etc. Rokeach suggests that such beliefs can be considered as being axiomatic and have a "taken for granted character". These type of beliefs can be described as being primitive in as far as they represent the basic

truths a person has about their nature and of physical and social reality. Included in this system are beliefs about the constancy of physical objects and the constancy of others with respect to physical objects.

In the model being proposed in this work, the changes that are modelled as taking place between agents' knowledge configurations are in the area of the agents' derived beliefs and beliefs concerning matters of taste. Changes in these beliefs have fewer functional connections and consequences for other beliefs and it is argued that it is on this level that much of the normal day-to-day interaction and communication between agents is concerned. However, the more primitive beliefs have a bearing on what is mutually agreed between the agents and the way in which they cooperate in the communicative interaction. Much of what relates to this aspect has a taken for granted characteristic similar to that of primitive beliefs and only becomes an issue when an agent departs from what the other agent considers to be normal.

### **3.1.5 Wants and goals**

Galliers (1989) in her model suggests that:

"Goals characterize what is implicit in the agent's desires. Having a goal that  $p$ , describes what the world would be like if  $p$  were true. This means that implicit in an agent's goals are all the logical consequences of those goals, just as having one belief means all the logical implications are also believed. A goal is a state of the world, and it is the state of the world the attainment of which, is desired by the agent. Attainment of the state thus satisfies the goal" (Galliers, 1989: 44).

This definition used by Galliers in her theory, is determined by the particular formal approach which she has adopted in modelling beliefs derived from a representation using modal operators in a possible-world semantics (following Hintikka, 1962). In a possible-world semantics agents know all the logical

consequences of what they know and believe all the logical consequences of what they believe. The same characteristic, because of the formalism used, is also applied in her scheme to the formalization of goals. This characteristic is one that bedevils possible-world semantics but is too strong for models of human dialogue. This is a characteristic of ideal belief systems but it has been previously noted that human rationality and human belief systems are imperfect and a formalization for intentions, beliefs, and goals needs to be found to account for imperfect rational belief systems.

Agents have multiple goals some of which are long term, others of which are more short term and immediate. The immediate focus of this present work is on those goals that the agent is committed to in the process of dialogue. The view adopted here follows that of Galliers in accepting that the notion of commitment to a goal is important and that the existence of a goal presupposes some level of commitment. This is in line with Cohen and Levesque's work which defines a persistent goal as one which the agent will only give up, either when it is satisfied, or comes to believe that it is impossible to achieve or the reason for it no longer exists (Cohen & Levesque, 1987; Galliers, 1989: 45).

The term 'communicative goal' has been used throughout this work and deserves clarification. Galliers (1989: 46-47) defines its use in her theory as being used only to refer to the desire to induce changes in the knowledge configurations of others. The use of the term here is wider. It not only refers to the purpose for which the agent initiated or participates in the dialogue, but also refers to the goal of each utterance and the necessary changes that need to be made in the knowledge configuration of others to ultimately achieve that goal. In this sense, each of the sub-goals are part of the main goal and could be described as 'communicative sub-goals'. A response from the hearer to a speaker's 'sub-goal utterance' may result in the speaker either changing the original goal or even dropping it and therefore is related to the original purpose for communication. The term communicative goal in this work covers both these uses.

A major argument of this thesis is based on the premise that utterances bring about changes in the knowledge configurations of agents. It is necessary to look more closely at what is meant by this process.

### **3.1.6 Belief revision and changes in knowledge configurations**

Changes in the knowledge configuration and beliefs of agents can be brought about in a number of ways as agents are exposed to new and fresh information. This might result in the formation of new beliefs, adaptations and modifications to existing beliefs and sometimes result in a challenge or prove to be contradictory to existing beliefs. It may only mean that another piece of knowledge is added to the system. What we are concerned with in this present work are the changes in knowledge configurations of agents as a result of utterances occurring in the process of dialogue.

Before proceeding further it is important that I clarify what is meant by the term 'knowledge configuration'.

This work is sympathetic to Galliers (1989: 29) view, that Cohen & Levesque's (1985) work and others (see Galliers, 1989: 29) is an advance from earlier work which is primarily a theory of communication in terms of mental states and how these lead to action and the subsequent effects of those actions on mental states. However, I believe the use of the term 'mental states' can be misleading and needs some clarification.

Despite this being a term that is used extensively in the literature, writers and researchers generally do not clarify what they mean by it and Baker & Hacker in particular have challenged its use as being ludicrous. They say:

".... the belief that to know something is to be in a certain mental state.

This is a grave misunderstanding" (Baker & Hacker, 1984: 279).

and argue that moods such as cheerfulness, depression as well as excitement, terror and anger are mental states. Such states do not continue through loss of

consciousness, that is, one may be excited when one goes to sleep before a significant event but is not excited while asleep. They maintain that knowing is not a mental state as one's knowledge cannot be interrupted, only forgotten and later recollected or relearned (ibid: 279-80). Although what Baker & Hacker appear to be referring to may more appropriately be designated as emotional states and one may take exception to their view that knowing is not a mental state, I have chosen to avoid the term in an attempt to avoid any confusion. In this work a distinction is made between mental states which can be equated with emotional states and the changes in a person's knowledge configuration that are brought about by being exposed to the process of dialogue and any new information displayed in this process.

Therefore, instead of the term 'mental states' I will use the alternative term 'knowledge configurations'. I believe that this term is more perspicuous for my purpose and relates more explicitly to the changes in elements of knowledge that come about in the process of dialogue. In this work 'knowledge configuration' will refer to a person's knowledge and belief set at a particular point in time. It relates specifically to the set of beliefs a person has which relate immediately to the dialogue in progress.

### **3.1.6.1 Manipulation versus display**

Galliers (1989: 68) and Allwood (1976: 73) take the view that changes in agents' knowledge configurations (Galliers' mental states) are brought about by the 'manipulation' of one agent by another. Both argue that it is plausible that agents are able to manipulate the knowledge configurations of other agents by what they say. Galliers uses the concept in her work without defining what she means by it and appears to leave the reader to understand the term in its normal and everyday sense. I find the use of the term in this context problematic, and believe that Galliers' use of it is somewhat inconsistent in relation to some of her other claims for agents, i.e. that agents have autonomy over their knowledge configurations and are viewed as being able to control what they believe and what they reveal:



"Agents are considered autonomous. They have control over the flow of information in the multi-agent system, both in terms of what they acquire and what they reveal" (Galliers, 1989: 34).

To change someone's mind about some state of affairs according to Galliers, is to alter the context of a person's knowledge configuration thus changing conflict into cooperation. She adopts the view that the role of dialogue is the instrument by which agents can manipulate these knowledge configurations (Galliers, 1989: 8).

The problem with her use of the verb 'manipulate' is that it is a term which seems to imply that an agent can manipulate the knowledge configurations directly in the same way that an agent can manipulate the controls of a machine or use their hands in a manual task. The implication that agents can directly manipulate the knowledge configurations of others, conflicts with the claim that agents have autonomy over the knowledge configurations that they acquire or reveal.

Similarly, Allwood argues that:

"From the point of view of the sender, the communicative process begins when he consciously begins to manipulate the individuals around him" (Allwood, 1976: 73).

He defines the term and its use in this manner:

"By manipulation will be meant any action intended to bring about a reaction in another individual. The intention accompanying a manipulatory action will be called an evocative intention. The manipulatory action need not be apprehended by the receiving individual" (Allwood, 1976: 73).

I would argue that Allwood's use of the term is misleading and that it is an inappropriate term for its purpose. It is similar to a number of verbs that could be used in its place and which serve only to indicate what the intending agent is wanting to achieve. For example, to deceive, frustrate or lie. Each of these indicate activities by one agent to influence another but do not tell us whether the agent to whom the activity is done, undergoes any change in knowledge. What they do indicate is the intention of the intending agent and it is possible to conclude that the utterances made with such intentions carry illocutionary forces which could have an effect on the other agent's knowledge configurations.

What I believe to be a more useful term with respect to changing agents' knowledge configurations and which is another of Allwood's terms, is that of 'display'. (Allwood, 1976: 74). About such a term Allwood has the following to say:

"The first stage of evoking a conscious reaction is very often to get an individual to merely apprehend or attend to some specific object. We will call a manipulatory action which is intended to make a receiver at least apprehend or attend to a certain object, through some manner of apprehension like direct observation or inference, an act of display" (Allwood, 1976: 74).

Furthermore, Allwood argues:

"An act of display is thus a rather complex intentional action involving at least the following intentions, with some degree of awareness:

1. the instrumental plan governing the manner of display, and
2. the purposive plan governing the information intended to be communicated, based on assumptions about shared cognitive presuppositions and normal rational agenthood...." (Allwood, 1976: 75).

"...from the sender's point of view, manipulation can primarily aim at both unconscious influence and at conscious apprehension, but display always aims at apprehension first. Both activities can then aim at further reactions on the part of the receiver" (Allwood, 1976: 90).

Though Allwood's use of the term 'manipulatory action' has been rejected, what is being postulated here is that an agent has certain intentions in making certain utterances, the purpose of which is to change the hearers knowledge configuration to an orientation in which the hearer is able to apprehend information prior to the possible recognition of the speaker's intentions. In order for this to be possible the speaker displays the orientation of her knowledge configuration to the other participant by the utterances she makes. The receiving agent is confronted with the information and after apprehension has to make a choice or decision as to whether any change in her beliefs is in order. This sounds simpler than it is.

Knowledge configurations are fluid conditions and cannot but be affected by incoming information and therefore, are changing all the time, especially in the process of dialogue. Once an utterance is heard and understood by an agent, though the speaker could withdraw the comment, there is a sense in which it cannot be withdrawn and has an irrevocable characteristic about it. However, whether any more permanent changes take place within the belief system of the receiving agent, relates to the agent's autonomy over their own knowledge configurations and the decisions they make regarding the nature of the incoming information. An agent in making an utterance displays her own knowledge configurations in a specific orientation. The receiving agent is exposed to this orientation of beliefs by the sending agent which cannot be otherwise.

What effect this has on the receiving agent relates to her own specific orientation of beliefs and may have little or much relevance. If the display is of significant relevance it may bring about a change in the knowledge configuration of the receiving agent. Much depends on the content of the information displayed, the intention of the sending

agent, the illocutionary force of the utterance received and the relevance of this to the receiving agent. The use of the term 'display' has advantages over the use of the term 'manipulation' and preserves the concept of the autonomy of agents over their knowledge configurations in what they acquire and reveal.

Some brief space now needs to be devoted to an examination of the mechanisms the receiving agent employs to make the necessary changes to their knowledge configurations on the receipt of new and relevant information.

### **3.1.6.2 Association**

Incoming information associates or matches with the specific orientation of the hearer's knowledge configuration at that particular point in the process. Elements of the incoming information may already be present or activated in the receiving agent's knowledge configuration and therefore requires no further activation. They may be activated by the context in which the dialogue is taking place and in this respect salient to both participants. If not, additional incoming information will activate or elicit associations with previously stored information which then become part of the receiving agent's knowledge configuration. Associations are made when bits of incoming information are known and recognized and matched with previously stored pieces of information. In other words there is a matching or connecting of information that takes place and additional information can be said to fit with previously stored information.

It is likely that at some stage in the process new information will be available to the receiving agent which either has to be noted, accepted or rejected. Whatever, it influences in some way the current orientation of the receiving agent's knowledge configuration and this fresh information may involve a considerable amount of mental processing. Furthermore, connections might have to be made by the receiving agent as to how the new information fits with existing information as the connections may not be obvious or evident immediately. This process is described as inferencing.

### 3.1.6.3 Inference

Agents are able to draw conclusions or inferences from the information contained in another agent's knowledge configuration and to the extent that this knowledge configuration is displayed to them. A hearer has no direct access to the intended meaning of the speaker and often has to rely on making inferences to understand what is said. What enables them to do this is the enormous amount of existing background knowledge they have available to them. Gumperz (1982) puts it in the following manner:

"Conversationalists thus rely on indirect inferences which build on background assumptions about context, interactive goals and interpersonal relations to derive frames in terms of which they can interpret what is going on"

(Gumperz, 1982: 2).

Agents are actively constructing an interpretation of what they hear and exercising effort to understand and make sense of this. It is done by making connections between the social context and their existing background knowledge. Background knowledge underpins dialogue and the larger the pool of background information participants in a dialogue share together, the more likely their conversation will be condensed and abbreviated. This is for the reason that fewer connections have to be made, as agents who know each other intimately share a greater fund of background knowledge.

As a consequence, they are able to make more assumptions about each other and many of the connections they need to make are made automatically. The ability to draw conclusions about the behaviour, beliefs and intentions of other persons, relates to a person's consciousness and to the way a person perceives themselves being seen by others. Allwood (1976) suggests that the ability has to do with social competence. His construal of inference making is:

"Drawing conclusions is here to be construed in a broad sense as inferential ability, ability to notice connections, similarities and analogies on the basis of earlier experience of particular individuals and the world in general" (Allwood, 1976: 94).

He claims that this is not only a part of social consciousness and competence but is the kind of ability that makes it possible for an agent to interact with other individuals. Brown & Yule (1983) appeal to the rather general notion of inference and describe it as that process which:

"...the reader (hearer) must go through to get from the literal meaning of what is written (or said) to what the writer (speaker) intended to convey" (Brown & Yule, 1983: 256).

They suggest that information can be seen in formal terms as the missing link which is required for an explicit connection to be made between one item and another and therefore, it might be possible to envisage inferences, necessary to understand utterances, as the process of filling in the missing links (ibid: 257).

They discuss a distinction between two categories of missing link. A kind that is made automatically and those they describe as 'bridging assumptions'. The distinction is made on the basis that bridging assumptions take processing time and automatic inferences don't. As a consequence they suggest that the missing links that are made automatically should not be described as inferences (ibid: 259-262). It is helpful to look at their arguments a little more closely.

The conclusion that 'bridging assumptions' take more mental processing time derives from the work of Haviland & Clark (1974) who found that determining the referent for *the beer* in (3.2b) took readers significantly longer to process than in (3.1b):

- (3.1) a. Mary got some beer out of the trunk.
- b. The beer was warm

- (3.2) a. We checked the picnic supplies.
- b. The beer was warm

(Haviland & Clark, 1974: 514-515)

The understanding of (3.2) requires a particular inferential process which is described as being a 'bridging assumption' between (3.2a) and (3.2b) which is:

- (3.2) c. The picnic supplies mentioned include some beer

The argument being that this type of bridging assumption takes time and accounts for the difference in comprehension times noted between (3.1b) and (3.2b). Brown & Yule suggest that the implication from this type of research finding is that inferences take time (ibid: 257).

Automatic inferences are somewhat different and they cite the following examples:

- (3.3) a. I bought a bicycle yesterday
- b. The frame is extra large

- c. The bicycle has a frame

- (3.4) a. I looked into the room
- b. The ceiling was very high

- c. The room has a ceiling

- (3.5) a. This afternoon a strange man came into my office  
b. His nose was purple

c. The man has a nose

(from Brown & Yule, 1983: 257)

They suggest that in each of these examples, the missing link expresses information which we might expect to be represented in one of the stereotypic knowledge formats (e.g. frames, scripts etc.). Brown & Yule argue that if the distinction is to be made between inferences as bridging assumptions that involve processing time and automatic inferences as indicated in these examples, then it would follow that those missing links which are automatically made are not rightly described as inferences (ibid: 259). There are some difficulties that need to be identified with their argument and the examples they have used to support this.

Firstly, they argue that inferences such as bridging assumptions take time on the basis of the example in (3.2). On the surface this example is problematic in terms of processing time and being able to distinguish the difference in this between (3.1) and (3.2) as Brown & Yule do not make clear whether this could be due to a repetition effect of the words used in the sentences. However, Haviland & Clark were aware that their results might have arisen because of the simple facilitating effect of repetition (ibid: 515) and carried out experiments to control for this. They found that the mere repetition of the critical noun was not enough to account for the length of time taken in the initial experiments and concluded that the first sentence of these couplets was new information that needed to be attached to previously processed information in memory (ibid: 512)

The argument that (3.3) - (3.5) should not be seen as inferences is correct because no missing links can be identified and no connections have to be made. This postulation is made on the basis of the following argument. How many bicycles don't have frames? How many rooms don't have ceilings and how many men don't have



noses? Whilst a room might still be a room without a ceiling and a man still a man without a nose, would a bicycle be a bicycle without a frame? Many objects are known for what they are because of the characteristic parts that constitute them as being that object. That men have noses is likely to be an existential type of belief (3.1.4.2 & Rokeach, 1968: 5) and only noted as being different when a person is seen as being deformed in some manner or has been injured.

I am suggesting that much of our knowledge is stored either in a 'frame' or 'mental model' type of organization which helps to explain this phenomenon. When a particular frame or mental model has been activated in memory the essential parts that constitute the basic model are necessarily activated along with that model otherwise it would not be a mental model of that item. For example, reference to a bicycle would activate a mental model of a bicycle in which a frame, two wheels, handle-bars, saddle and pedals are likely to be part of the model. One would have to know what a bicycle was to have such a model activated. The frame appears to be an item that is essential to the idea of a bicycle and without one, one is left with an assortment of bicycle parts.

The concept of frame or mental model can be used to explain representations either in terms of a 'whole' or if necessary, its individual parts can be used. The individual parts can be added to or deleted, depending on the task and the use of the model. Similarly, a person is likely to have mental models of rooms, the stereotype of which is likely to have a ceiling and also mental models of faces which are likely to require the presence of a nose. Many connections between one item and another can be made on this basis. Items can be retrieved from mental models with ease for they are present within the model and only focus, attention or reference is required to activate individual parts of the model.

The examples which Brown and Yule (1983) initially termed as automatic inferences can be dealt with by reference to 'mental models' or 'frame-like' conceptions of knowledge organization but the inferences they term as bridging assumptions suggest as having to be dealt with differently. While I query the use of their particular example on which they base the argument for processing time for these

type of inferences, I believe their argument has some value and relates to the possible time it might take for some connections to be made in mental models.

For example, the connection in a mental model between (3.2a) and (3.2b) that beer was included in picnic supplies might take longer to make because beer might not be a normal part of an agent's model of picnic supplies. Brown & Yule make a similar point about a group of real ale enthusiasts who often indulge their enthusiasm on picnics. It is likely that beer for them would be an automatic component of their mental model of picnic supplies (ibid: 263). If this is the case it poses a problem for any distinction between 'automatic' or 'non-automatic' inferences and points to all inferencing as being related to the distance or depth of processing required to make connections between different items of information.

Some of the elements of Brown & Yule's discussion of inference are valuable for present purposes. I would wish to argue that inferences can be interpreted as being missing links of information or seen as information that is not immediately present or in focus for the hearer and thus requiring mental processing in terms of making connections.

Connections are made between different items which constitute mental models and different connections may need to be made between different mental models or more complex models. Some of these connections are made more or less automatically because the connections are present as essential and constitutive parts of the mental model. In other instances the mental model has to be developed and information from other models has to be retrieved for incorporation into a particular mental model which might take some mental processing time. Elements of this theory are incorporated into the model of dialogue to be presented in chapter four. In my model agents derive connections between pieces of information which are obtained from frame-like structures containing representations of their beliefs.

### **3.2 Summary**

The major elements that are viewed as being necessary for a theory of rational action and interaction have been identified and shown how they relate to this work.

It has been argued that dialogue is a purposive activity of intentional human systems who are viewed as being rational, albeit with an imperfect rationality. These intentional systems are also belief systems and the beliefs, wants, goals and plans characteristic of such systems activate and derive from intentions and intentional action. This occurs within a context of multi-agent rationality, cooperation and shared knowledge.

In the following chapters a descriptive model of dialogue is presented which is derived from the theory presented here.

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## **Chapter 4 - A model of natural language dialogue**

It has been noted in the foregoing chapters that there are at least two major emphases in conversation analysis both of which tackle the problem from very different directions. For example, there are the speech act theorists who focus on the individual utterances of speech and appear to ignore the context in which individual utterances are made. On the other hand there are those researchers and analysts of conversation who view all utterances as being part of a sequence and consider that it is not appropriate to divorce a single utterance from its context within the conversational process. They argue that an utterance needs to be examined, not only in relation to the wider context but also as a unit among other utterances which it might be part of and in its appropriate place within the conversational sequence. I am in some sympathy with both approaches and utilize insights from both fields. However, the tension between these two approaches helps to identify the problem with which my research is concerned.

The major idea of this thesis is that dialogue is motivated by the goals and purposes of the participants. These initially are in the form of beliefs, attitudes and intentions. Agents construct plans by which their communicative intentions and associated goals are achieved and which culminate in individual utterances until goals and purposes are either fulfilled or aborted. The result of such interaction is a dialogue or conversational sequence. The purpose of this present chapter is to identify and to describe the components of a model of natural language dialogue and show how these might work together in the process of dialogue.

In delineating the components of this model, the reader should bear in mind the type of model that is being constructed here and the comments made about such models that were more fully described in 1.8. The model presented here is not a scale model neither is it an analogue or mathematical model. It is a theoretical model and therefore, in Black's terms, "a certain way of talking" (Black, 1962: 229). The advantages and disadvantages of this type of model were discussed in 1.8 and I do not

intend to repeat the arguments here. What needs to be emphasised here is that the components of the model to be described are viewed as being the strategic components necessary for inclusion in any proposed model of dialogue and therefore, likely to be among the most important elements in a theory of dialogue. It is likely that such major components are supported by a host of other subsidiary functions and operations. Though nonetheless important, these are not my major concern and therefore are not detailed in any specific manner within the model.

What is presented here is a precise arrangement of the knowledge configurations of two agents involved in a particular piece of communicative interaction. In this selected piece of interaction the agents each have individual and disparate goals to achieve. This is accomplished by communicative interaction and negotiation. They are not involved in a joint task as the possible outcomes of the interaction are very different for each of them. However, each of the agents can only achieve their goals if both agents are successful in achieving their individual goals. It is possible for one of the agents to achieve their goal at the expense of the other whilst the other agent has the power to see that neither goal is achieved.

Nevertheless, in order to achieve their different objectives the participants need to cooperate on a communicative level and only by each of the agents pursuing their own goals will each succeed in achieving their individual goals. Each agent brings to the interaction a different set of beliefs, attitudes and intentions. Furthermore, each agent has attitudes about the beliefs and intentions of the other agent. The net result is what Power describes as a set of "interlocking mental states of great complexity" (Power, 1984: 87).

The agents involved are assumed to function on rational principles and their utterances are seen to derive from their intentions based on their beliefs and attitudes. Goals are achieved by the agents in an exchange of utterances that derive from the changes in knowledge configurations of each of the agents as the dialogue progresses. It takes place within a context of rational cooperation in which much knowledge is shared or held in common.

## **4.1 Syntax, Semantics and Pragmatics**

The organization for a natural language comprehension system is viewed by most researchers to require three phases: syntactic parsing, semantic interpretation and contextual interpretation and many textbooks which address the subject of language, approach it along these three major dimensions as do numerous researchers (Allen, 1987; Winograd, 1972). Whilst such an approach may be helpful to the student in enabling the subject to be grappled with in a manageable form, the delineation of the subject area in this manner remains an academic artifice and may prove at times to be a hindrance rather than an advantage.

An inherent danger in such an approach is the thinking that psychological processes governing language comprehension might be organized on the same basis. As a consequence, various syntactic models have been put forward as models of language production and comprehension but which demand ever increasing semantic and pragmatic inputs to make them anywhere near to being feasible models. It needs to be emphasized that such processes, while useful to describe in a linear manner, probably operate in reality in a closely integrated and parallel fashion.

Nevertheless, having identified certain dangers with this approach it is useful to think in terms of the three major dimensions of natural language comprehension as they enable us to think about the relationships between these different types of knowledge and how they might function together in the production of utterances.

## **4.2 How entities are represented in the model - an overview**

My immediate concern is not about how the different aspects of knowledge (syntax, semantics, pragmatics) come together in the process of language but more particularly how a person's beliefs and goals motivate and produce the utterances that speakers make. Therefore, it is useful to make a distinction, between semantic, pragmatic and contextual knowledge on one hand and syntactic knowledge on the other. Though such a distinction may be blurred in reality, the phenomena relating to these respective areas makes the drawing of some distinction more viable than that

sometimes made between semantic and contextual types of knowledge. A distinction is made between these different aspects of knowledge here for the purpose of showing how semantic and contextual knowledge might be implemented by syntactic knowledge.

In this model, the beliefs of the participants are made up of individual concepts which combine with others in certain relationships to form more complex types of belief. I have followed the propositional system of Kintsch (1974: 13) for this purpose and the reasons for this as well as the system itself are described below. These beliefs might be about anything and by their very nature have a semantic content. The belief-set of each agent also includes beliefs about the context of the speech situation. The model attempts to demonstrate how utterances are planned given a set of beliefs and a particular set of goals relating to these beliefs. More specifically, participants in a dialogue can be viewed as having a set of beliefs about the world.

From this set of beliefs, goals are formed and the making of utterances are a means of achieving these goals. Utterances can be made in a variety of ways but have to be planned for. This process is modelled for two agents and culminates in each producing a proposition in logical form prior to each utterance being made and which relates to their individual goals and purposes. The individual propositions, which contain elements of the beliefs and concepts directed at achieving a goal, are displayed to the other agent thus creating the process of dialogue.

No attempt is made to model the syntactic or grammatical form of the agents' utterances and therefore the propositional forms are not transposed into a completed grammatical parsing. Much work has been done in the area of computational linguistics and parsing and it is not my purpose to replicate this work here. It must be noted that the computational linguistic approach to language has not been as successful as initially hoped for, for the reasons that a purely syntactic approach to language generation or comprehension will not work. As noted above, language has a semantic as well as a pragmatic component and these other components are likely to work with the syntactic component in a synchronized and parallel manner.

Syntactic models and parsing components require semantic and contextual information to be integrated. One of the objectives for the model presented here is that it can serve as a semantic and contextual component of such an integrated model. Though it is not my intention to model the syntactic element of language I do show how the logical form of utterances derived from agent's initial belief sets could be used by a parsing or syntactic component, using Allen's (1987) syntactic notation and presentation.

The way in which the agent's beliefs are represented in the model is described first. The belief-sets of the respective agents consist of their general beliefs, beliefs about the context, goal-beliefs, beliefs about plans and plan-methods which are used to achieve specific outcomes. This is followed by a description of the logical form representation for the model. Elements from the particular sets of beliefs contribute to the planning and construction of a logical form which is formed prior to the utterance being made and guides the syntactic construction of the utterance.

#### **4.3 The representation of beliefs in the model**

It has been noted that knowledge as well as beliefs are likely to be stored in memory in some form of structure (3.1.4) and that there are likely to be operations that act on these structures. Of concern to philosophers, psychologists as well as cognitive scientists are the operations permissible within these structures, that is, the processes of thought that reflect the phenomenon of 'natural logic'. As a consequence, many an investigator, in an attempt to understand the intricacies of natural language, has turned to standard logic for an instrument to assist in this task.

Standard logic is a medium that has attracted many researchers, especially those in AI, because of its deductive capacities for exploiting language and knowledge. Even so, standard logic does not describe human thinking for the reason that it is a prescriptive formal language. It was developed to permit unambiguous, correct inferences and it achieves this by making a clear distinction between logical syntax and semantics. What are acceptable well-formed formulas (wff's) i.e. expressions and



proofs, are determined by the syntactic rules of standard logic while its semantics is concerned with truth values in possible worlds.

In natural language and natural logic no such priority is given to syntactic-formal rules and it is impossible to separate syntactic aspects of language from semantic considerations. To understand an utterance is to compute its meaning and to do this, syntax as well as semantic and pragmatic characteristics must be understood. As a result, several researchers have tried to construct semantic memory models with a disregard for standard logic (Anderson & Bower, 1973; Collins & Quillian, 1969; Kintsch, 1974; Rumelhart, Lindsay & Norman, 1972; Schank, 1972; Winograd, 1972).

Kintsch (1974) is an investigator who has developed a model of semantic memory based upon the notion that propositions (3.1.4.1) are the basic elements of the semantic structure (ibid: 47). A problem he confronted in taking a non-standard approach to natural logic was to determine the adequacy of the proposed formalism of a propositional model as a base for natural language (ibid). He set himself the task of investigating the adequacy of a propositional model for this purpose and concluded that it was sufficiently powerful and explicit to account for at least some aspects of the classic topics such as quantification, definite and indefinite reference, modality, tense, implication and presupposition.

Kintsch's propositional theory and system is suitable for representing the belief system in my model. As previously noted, his system was designed as a base for natural language but I am using it to represent the belief base of agents. A complete description of his system is therefore not necessary for my immediate purpose and the interested reader is referred to his text for this. What I propose to describe are the basic elements of the formalism that have relevance for the immediate task in hand.

There are a number of problems that representations of agent's beliefs have to deal with. Firstly, a distinction needs to be made between the explicit beliefs of an agent and their implicit beliefs. Abstract relationships such as actions and plan structures also need to be represented. Other problem areas concern the representing of nested beliefs,

shared beliefs and beliefs about others' knowledge, beliefs, abilities and plans. Not all these problems are addressed by this model but what is required for present purposes is a form of representation for beliefs which is both clear, elegant, and one that shows how the initial beliefs come together to formulate a structure for realizing an utterance to achieve a goal or plan. This structure is the logical form for the proposed utterance.

A major premise of this work is that the essential concepts and the relationships between them, are present in the belief structure that motivate the formulation of a goal or plan which results in speech. Therefore, an initial task is to identify the elements that will eventually be realised in natural language; as well as the abstract relationships that are present in the belief structure. The concepts and elements in this structure are used to form nouns, verbs or verb phrases, referents, tense, case, number and modality in the surface natural language.

#### **4.3.1 The basic elements of Kintsch's propositional system**

Kintsch argues that the semantic base of a text consists of ordered lists of propositions (ibid: 13). Propositions consist of elements which are word concepts, i.e. lexical items, and contain a predicator and  $n$  arguments ( $n \geq 1$ ). Word concepts may be used either as arguments or as predicators. I am using propositions to represent beliefs and therefore, word concepts represent elements of a belief. Although these are identified as being lexical items I am not concerned with a lexicon as such or how this might be accessed in the process of dialogue.

The element of a belief consisting of the word concept BOOKSELLER might be realised in the lexicon as the English word *bookseller* though under some circumstances it could be realized as *sales-person* or *shop assistant*. In Kintsch's system it is the task of the lexicon to specify permissible combinations of arguments and predicators but in my model this task is carried out in the construction of a logical form (to be explained below). In describing the system a number of conventions are observed. Propositions are enclosed by parentheses and appear in upper case; predicators are written first and all terms are separated by commas. A belief that is not

known is signified by the tilde before the action KNOW, i.e. ~KNOW. The following are some examples:

- |       |   |  |
|-------|---|--|
| (4.1) | Booksellers sell books                            | (SELL, BOOKSELLER, BOOKS)  |
| (4.2) | Customer wants book                               | (WANT, CUSTOMER, BOOK)   |
| (4.3) | XYZ is a book                                     | (BOOK, XYZ)  |
| (4.4) | Books cost money                                  | (COST, BOOKS, MONEY)   |
| (4.5) | A book has papercovers                            | (HAVE, BOOK, PAPERCOVERS)  |
| (4.6) | A book has hardcovers                             | (HAVE, BOOK, HARDCOVERS)   |
| (4.7) | The book is valuable                              | (VALUABLE, BOOK)   |
| (4.8) | If bookseller has bookXYZ<br>customer will buy it | (IF, (HAVE, BOOKSELLER,<br>BOOKXYZ),<br>(BUY, CUSTOMER), BOOKXYZ)) |
| (4.9) | Customer doesn't know price<br>of book.           | (~KNOW, CUSTOMER) &<br>(VALUE- £15, BOOKXYZ)                       |

In 4.1, 4.2 and 4.4 - 4.6 the predicators are verbs. In 4.3, a noun is a predicator. IS-A could have been used here as a predicator but the copula is omitted in the base expression for the sake of consistency as it is in 4.7. The latter illustrates the use of an adjective as a predicator. In 4.8 a conjunction is used and this example shows that propositions may be embedded within other propositions as their arguments. An alternative notation is available for embedded propositions as it is sometimes preferable to separate embedded propositions notationally. This is achieved by providing the embedded propositions with arbitrary names and for this purpose I identify these by using letters of the alphabet. An alternative way of writing 4.8 is:

(4.10) (IF, a ) & ((HAVE, BOOKSELLER, BOOKXYZ) = a) & (BUY, CUSTOMER, BOOKXYZ)

The ampersand is used to connect propositions, the order of which can be significant. Often the first proposition establishes some position or that some object exists and the remainder of the expressions make certain statements about this fact. For example:

(4.11) *The old man smiled and left the room*  
 (OLD, MAN)&(SMILE, MAN)&(LEAVE, MAN, ROOM)

whereas:

(4.12) *Mary claimed that the old man smiled and left the room*

would be represented as:

(CLAIM, MARY, a )&((OLD, MAN)&(SMILE, MAN)  
 &(LEAVE,MAN,ROOM) = a )

When two or more propositions are connected, recurrent terms, i.e. word concepts, are assumed to have identical reference. For example, the second appearance of the argument BOOKSELLER in the belief base always refers to the BOOKSELLER previously introduced. If this identity of reference is not required a special notation can be introduced to distinguish between the items, in the form of index numbers, e.g. BOOKSELLER1 and BOOKSELLER2. A complete list of beliefs used in this model appear in Appendix 1.

#### 4.3.2 The representation of beliefs about context

A particular class of representations for natural language are case structures. Traditionally, the notion of 'case' relates to the classification of noun forms according to their inflection and in languages such as Greek, gender and number are indicated by inflectional forms. Attempts were made to relate inflections to cases in the surface

structure of language but often became bogged down in semantic as well as linguistic problems. This led to a distinction being made between 'surface cases' of the syntactic level and 'deep cases' of the semantic level. Fillmore argued that the characteristic of deep cases might be a universal characteristic of language:

"...what is needed is a conception of base structure in which case relationships are primitive terms of the theory and in which concepts such as 'subject' and 'direct object' are missing. The latter are regarded as proper only to the surface structure of some (but possibly not all) languages" (Fillmore, 1968: 2-3).

The idea behind deep cases is that they are useful for accounting for the acceptability of some sentences and for explaining how an intelligent system might understand language. This is because the selection restrictions associated with cases place semantic constraints on which objects fill case slots. It is useful to illustrate the notion of deep cases by describing an event and the following is an example for this purpose adapted from Bruce (1975:331-333). He suggests that events can be thought of as primary entities that can be interpreted in terms of a large set of unary predicates which classify these events and which can then be quantified over. For example the event of 'kicking' in the following:

(4.13) *Susan awkwardly kicked the football to Mary with her left  
foot in the park*

can be represented as:

(4.14) (\$x) (kicking (x)  
& agent (x, Susan)  
& object (x, football))

& time (x, past)  
& manner (x, awkward)  
& goal (x, Mary)  
& instrument (x, a1)  
& location (x, a2)

(where a1 represents "her left foot" and a2 "in the park")

What Bruce draws attention to is that an indefinite number of properties may be specified for a given event and that some of these properties are important and significant while others are modifying properties. Furthermore, he concludes that the grouping of properties is sensitive to context which include the purpose of the speaker and the beliefs of both speaker and hearer. Bruce suggests a number of criteria for deep cases which are pertinent to this work.

A case is a property

- (1) which must be used to distinguish different senses of a word
- (2) which must be used for unique specification of an event
- (3) whose value needs to be known, even if it is not explicitly specified
- (4) whose value is usually specified for a given type of event
- (5) which is particularly relevant to the domain of discourse
- (6) A case is a relation which is 'important' for an event in the context in which it is described

(Bruce, 1975: 333- 335).

These criteria are in harmony with the main thrust of this thesis. Case has been a notion widely used in language understanding systems (Bruce, 1975; Haas & Metzler, 1989; Huddleston, 1970; Kintsch, 1974: 23-25; Schank, 1972) and is a notion

adopted in this model for the purpose of identifying the significant properties of the context in which the dialogue interaction takes place. The beliefs each agent has about the significant properties of the context present in the dialogue event are captured in CONTEXTFRAMEs. These are frame-like structures possessing slots that take certain types of fillers that govern the use and meaning of the CONTEXTFRAME. As a consequence, each agent has knowledge of a range of cases and those relevant to any particular speech event are identified and used to guide the construction of the pre-utterance logical form. Bruce's criteria 2-5, are therefore particularly salient for this perspective.

Case grammar has been an influential approach for computational models as one of its most intriguing claims is that the number of possible semantic relationships is quite small although there has been little agreement among researchers as to what this small set consists of (Allen, 1987:199; Bruce, 1975: 335-336; Haas & Metzler, 1989: 535). Different sets of cases are proposed by different researchers. Allen suggests that this is best explained by the fact that they base their semantic analysis at differing levels in the hierarchy. A full list of the cases that are used in this model appear in Appendix 3 and the definitions for these appear in Appendix 4.

#### **4.4 The representation of goals in the model**

Goals of the agents are represented as propositional belief structures. Goal-beliefs are distinguished from general beliefs by the action-type entities which form the predicator of the proposition otherwise they are indistinguishable. A mechanism for deriving an agent's goals from their belief-sets is not described and a set of goal-beliefs are prescribed to each agent. This is for the simple reason that the problem of goal formation is not a research aim of this work.

Each agent then, has a goal they wish to achieve represented as part of their belief-set. The individual propositions that comprise the goal-belief act as sub-goals and represent the elements of beliefs that are required to fulfil the goal. On one level, the sub-goals represent the plan of the agent to achieve their overall goal. These sub-goal

propositions are constructed into a goal-tree from which an overall plan is derived to achieve the goal. The general-belief-set (GBS) contains other belief propositions that indicate what information is known or not known and which might be required for the achievement of a sub-goal.

#### **4.5 The representation of plans in the model**

A similar structure to that of CONTEXTFRAME is used for representing planning components of the model. A large number of plans could be represented but this is not the purpose of the model. The major idea behind the planning component of dialogue is that there are a great many stored plans as well as parts of plans that can be constructed to realize communicative goals. An objective of the model is to show how this might work. These planning components are represented as plan-methods which are described below (4.6).

Three of the most fundamental sentential mood choices in English are those of the assertion realized by declarative utterances; the question or asking action realized by interrogative utterances and the command realized by imperative utterances. These three options form the planning components of the model. To participate in the dialogue each agent has to know how to display information and uses the DECLARE plan-method to display their knowledge configuration. The ASK plan-method is used to obtain a display of the other agent's knowledge configuration while the COMMAND plan-method is available for making urgent and imperative utterances. Each of these plan-methods, i.e. DECLARE, ASK and COMMAND have procedures attached to them in the form of functions for the purpose of formulating other actions.

For example, an agent might wish to know something which can be viewed as being either one thing or another where only two options are available for an answer i.e. 'yes' or 'no'. On the other hand an agent might wish to know something where the options available may be one or more. That is, an agent/customer might wish to know whether a book has papercover bindings in circumstances where a book has a number of possible bindings such as papercovers, hard board covers or has a leather



or plastic binding etc. The subplan relating to the former type question is called a KNOWIF plan-method while the latter is a KNOWINFO plan-method. Similarly, the DECLARE plan-method has two associated plan-methods, namely INFORMIF and INFORMINFO which are the counterparts of the question plan-methods. KNOWIF and INFORMIF deal with yes/no type questions and answers while KNOWINFO and INFORMINFO deal with those options which might require the provision of certain pieces of information.

#### **4.6 The representation of plan-methods in the model**

The entities formulated as plan-methods are action-type entities that can be viewed as the sub-components of plans. An agent/customer might formulate the plan to visit a book shop to purchase a particular book and exchange some money for this. The methods and procedures by which this objective is accomplished might include an assortment of actions such as walking to the shop, looking for the book, asking the shop assistant for it if it cannot be found, purchasing it and paying for it. This general plan can be broken down into its individual sub-components which can be characterized as a number of methods to achieve each stage in the plan. It is these sub-components of general plans that have been characterized as plan-methods. They are methods employed by agents to achieve a particular stage of a plan and which allow the general plan to be aborted or changed at any stage.

The notion of plan-method is employed by the model for a number of functions that can be signified as actions and is another type of knowledge structure possessed by the belief systems of the respective agents. In the model, plan-methods are represented as word concepts that might eventually be associated with a lexical item of the same kind. These are referred to as undefined primitive predicates and are basic types of action that relate to verbs such as 'want' and 'buy'. They remain undefined and are not reduced further to any small set of primitive concepts (cf Schank, 1972). Plan-methods are small sequences of actions used to initiate utterances or perform other actions such as WANT and BUY.

They are frame-like structures containing slots. Selectional restrictions govern what can fill a slot or whether it contains another plan-method or a function. There are several plan-method type actions such as WANT, SELL, HELP, EXCHANGE-MONEY, OFFER-ASSISTANCE, GET-INFORMATION and a complete list of these is given in Appendix 2. Plan-methods can be used to execute DECLARE, ASK and COMMAND plans which in practice are themselves characterised as plan-methods. Plan-methods often execute other plan-methods in the process of obtaining the appropriate utterance. An example of a plan-method structure is:

<b>NAME:</b>	WANT
<b>OBJECT:</b>	?BOOK
<b>FROM:</b>	?(possibly bookseller)
<b>TO:</b>	?(possibly customer)
<b>ACTION:</b>	POSSESS-OBJECT (another plan-method, function or goal state)

An advantage of representing beliefs in this manner is that it helps to capture succinctly, some of the knowledge that is associated with these type of belief objects. For example. It is very difficult to define SELL without some reference or knowledge to BUYing or of PAYing without some reference to the concept of EXCHANGE. Such beliefs and concepts have as part of their definition aspects of the other concept. They can be understood in terms of the two sides of a coin in that you cannot have one side without the other. In one sense they can be seen to be defined by other plan-methods and therefore, their definitions appear to be circular and unreducible to further primitive concepts or actions. These type of beliefs are multi-dimensional and a frame-like structure is used to represent them and the selectional restrictions they require. The purpose of this is to capture essential knowledge that the propositional representation fails to demonstrate without much greater complexity.

There is a slight similarity between plan-methods and the notion of script. The notion of script is a significant one and has been used to characterize stereotyped sequences of actions (Schank & Abelson, 1977)<sup>2</sup> The similarity that the two notions share is the apparent phenomenon of 'chaining'. One event appears linked to another and suggests the idea of cause and effect. This is a characteristic of plan-methods where a plan-method might be linked to another plan-method and that in turn might be linked to yet another plan-method to achieve a certain outcome. This is the only similarity and the reader is given the opportunity of comparing the notion with an example of a script provided in Appendix 5.

#### **4.7 Deriving a Logical Form for utterances**

Allen (1987: 193) argues that to derive the syntactic structure of a sentence is just one step towards the goal of building a model of the language understanding process. What is further required, is an understanding of how word meaning as well as sentence meaning along with general world knowledge is used in the process of comprehension.

The approach Allen adopts for dealing with this problem is to divide the problems of semantic interpretation into two stages. In the first stage the appropriate meaning for each word is determined and these meanings are then combined in a logical form. The logical form is then interpreted in the light of contextual knowledge, allowing a set of conclusions to be made from the sentence.

The logical form can be viewed as the intermediate representation between the syntactic form of the sentence and a contextual interpretation of the sentence. While the logical form resembles a logic, in several ways its syntax is closer to that of a syntactic structure.

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<sup>2</sup> The notion of 'script' has been discussed widely in the literature and Schank & Abelson's (1977) ideas are well known. A brief review of the concept of script as well as an example can be found in Appendix 5.

The problem I am confronted with in this work bears similarities to that identified by Allen (ibid). A premise of this work is that the semantic content possessed by words and utterances is contained in the concepts, beliefs, knowledge and goals of agents and that syntax is one of the mediums by which such semantic content is displayed to other agents. The entities I am focussing on in this model are beliefs, goals and plans which form agent's knowledge configurations. These entities possess a semantic content and the model presented here attempts to show how the semantic content of these entities motivate and organizes utterances. They need to be represented in a form which reflect the rationality of agents' thinking and the constraints that concepts have on each other.

Furthermore, these entities, or tokens that represent them, need to be stated in a form which is consistent, cohesive and without ambiguity. In other words, it is necessary to derive a logical form for the way in which beliefs are composed prior to formulation into utterances. This can be illustrated as a simple hierarchical process:

Belief configurations

Logical forms

Utterances employing syntactic structures

A logical form notation, similar to that employed by Allen (ibid) is considered to be both adequate and appropriate for this purpose. The logical form in the context of this model can be viewed as the intermediate representation between the beliefs and ideas motivating the utterance and the utterance that is realized in its syntactic construction. The use of it here differs from that of Allen who views the logical form as being an intermediate representation between the syntactic form of a sentence and its contextual interpretation. That is:

Syntactic construction

Logical form

Interpretation in context

Any decisions that require contextual knowledge in Allen's model, are not made in deriving the logical form. Instead, information from the sentence structure is recorded in the logical form for use later by a contextual analyser. A premise of my work is that cues from the immediate context as well as the wider context of a speech situation are known to the respective agents. Contextual information is contained in beliefs of the agents about the context in which the dialogue is taking place and therefore inform and influence the belief configurations of the agents involved. Therefore, in my model, beliefs about the context as well as the agent's knowledge about these contextual cues, are used in deriving a logical form for the utterance.

The rationale for choosing this form of representation to describe the model is that it has clarity without unnecessary complexity; it employs concepts which are stated in their English format and therefore, avoids the sometimes obscure characteristic of many formal language notations. It is also adequate for representing the components of the model in a parsimonious manner.

It might have been feasible to use Kintsch's propositional system throughout instead of using another notation for this aspect of the model. A disadvantage of doing so is that in deriving a logical form, the notational system as used by Kintsch could become unwieldy and unnecessarily complicated for the purposes required by this model. Kintsch's system was primarily designed, as has been noted, as a base for natural language understanding and therefore is appropriate for representing sentences and larger texts. Allen's representation of logical form, although designed for a similar purpose, lends itself to characterising pre-utterances because of the way it deals with case relations, utterance performatives, tense and connectives.

It will be necessary to introduce case relations as well as performatives into the notation and it is considered that Allen's form of representation is more appropriate for this purpose than that of Kintsch.

Another advantage of using two different notations is to distinguish between beliefs and elements of beliefs and how the logical form of an utterance is derived from these. The logical form is not only derived from the belief sets that relate to general beliefs of agents, but also from their beliefs about the context, their beliefs about plans of how to formulate utterances and their beliefs about plan-methods and how these enable them to carry out their plans. Each of these elements need to be represented in a logical form and Allen's type of representation is suitable for this purpose and can be modified to accommodate the basic elements of a propositional belief system as proposed by Kintsch.

#### **4.7.1 A description of Allen's Logical Form**

The Logical Form described here has been borrowed from Allen (1987) and adapted to suit the objectives of this research. It is necessary to describe the essential elements of the representation and to explain how they are to be used in this work. Allen's logical form is used for text understanding and is more comprehensive than that required for modelling the sample dialogue scenario demonstrated in the following chapter. Nevertheless, a more complete description of the logical form is given and though the level of detail might not be required for present purposes, it does serve to demonstrate how more complex utterance forms could be handled.

The representation of *Jack kissed Jill* in logical form would correspond to the following;

```
(4.15) (PAST s1 KISS-ACTION (AGENT s1 (NAME j1 PERSON
      "Jack")))
      (THEME s1 (NAME j2 PERSON "Jill")))
```

Each logical form statement is made up of the following components:

- an operator indicating the type of structure; in (4.15) PAST means that this represents an assertion of some event occurring in the past;
- the type of object - that is, KISS-ACTION;
- the modifiers of the object, which may be a list of logical form structures; in (4.15) the modifiers consist of two cases, AGENT and THEME.

Allen also employs a numerical representation for the names of the objects being described. In (4.15) a name for the instance of KISS-ACTION is *s1*. This is unnecessary for my purposes and inclusion of them only clutters the representations to no useful or explanatory purpose. Therefore, I dispense with numerical names for the objects in my model. They are retained in the examples here as these have been borrowed from Allen's text and illustrate his use of a logical form for text understanding. I am using a logical form to represent the belief-concepts of agents and the use of numerical identifiers are unnecessary for this purpose.

Other indicators of utterance structure will include PRES (simple present tense), FUT (simple future), and PAST (indicating the past tense).

This representation can be extended to represent noun phrases but is adapted in my model to represent belief concepts or propositions that mirror noun phrases that ultimately appear in utterances. Though these are viewed as being belief entities the terminology of noun phrases is retained as these are the entities that the beliefs reflect in utterances. The operator for simple noun phrases is used to indicate the determiner information so that it can be used by later processing. The possible combinations for unquantified NPs are as follows:

DEF/SING     definite singular reference (the book)

DEF/PL       definite plural reference (the books )

INDEF/SING   indefinite singular reference ( a book )

INDEF/PL     indefinite plural reference ( books )

The name and type for simple NPs are as expected, and the modifiers consist of any qualification produced by adjectives or other modifying phrases. Thus the logical form for the NP *The large boy* would be

(4.16) (DEF/SING BOY b1(LARGE b1))

The quantified NPs map to similar structures using different markers as appropriate. Thus the sentence *Each boy ate a large pizza* would be represented as:

(4.17) (PAST a1 EAT-EVENT (AGENT a1 (EACH b2 BOY))  
(THEME p1 (INDEF/SING p1 PIZZA (LARGE p1))))

For wh-questions, the wh-terms need a special marker in the logical form. Three forms are used - WH, WH/PL, and WH/SING - depending on whether the number is unspecified, plural, or singular, respectively. For example, the NP *who* has the logical form

(4.18) (WH p1 PERSON)

whereas the NP *which dogs* has the logical form

(4.19) (WH/PL d1 DOG)

Two special forms are used for NPs that consist of proper names and pronouns. The first of these was used in an earlier example - the operator NAME identifies an NP consisting of a proper name, and the name is listed in the position directly after the type. Modifiers can be added if needed. For example, the NP *Big bad John* might correspond to



(4.20) (NAME j3 PERSON "John" (BIG j3) (BAD j3))

For pronouns a similar form with the marker PRO is defined. Thus the NP *he* is represented as

(4.21) (PRO h1 MALE "he")

The logical form for NPs that describe events is virtually identical to the representation of event utterances, except that the marker will indicate a determiner rather than a tense marker. For example, the NP *The arrival of George at the station* would be represented as

(4.22) (DEF/SING a1 ARRIVE-EVENT  
(AGENT a1 (NAME g1 PERSON "George"))  
(TO-LOC a1 (DEF s6 STATION)))

whereas the sentence *George arrived at the station* would be represented by the logical form:

(4.23) (PAST a2 ARRIVE-EVENT  
(AGENT a2 (NAME g1 PERSON "George"))  
(TO-LOC a2 (DEF s6 STATION)))

Each of the four major utterance types has a corresponding logical form that takes the utterance interpretation as an argument. These are as follows. For declarative utterances, such as *The man ate a peach*, the complete logical form is

(4.24) (ASSERT (PAST e1 EAT (AGENT (DEF/SING m1 MAN))  
(THEME (INDEF/SING p1 PEACH))))

For yes/no questions, such as *Did the man eat a peach?*, the logical form is

- (4.25) (Y/N-QUERY (PAST e1 EAT (AGENT (DEF/SING m1 MAN))  
(THEME (INDEF/SING p1 PEACH)))))

For wh-questions, such as, *What did the man eat?*, the logical form is

- (4.26) (WH-QUERY w1 (PAST e1 EAT (AGENT (DEF/SING m1 MAN))  
(THEME (WH w1 PHYSOBJ)))))

For commands, such as *Eat the peach*, the logical form is

- (4.27) (COMMAND (INF e1 EAT (THEME (DEF/SING p1 PEACH)))))

Embedded utterances, such as relative clauses, can be handled in the same way as other utterances. Any pointers in an embedded structure are analyzed simply by inserting the name of the structure built for the constituent that is referenced. Thus the utterance *I want to leave*, with the syntactic form

- (4.28) (S SUBJ (NP1 PRO I)  
MAIN-V want  
TENSE pres  
COMP (S SUBJ -> NP1  
MAIN-V leave))

has a logical form of

- (4.29) (ASSERT (PRES w1 WANT  
(EXPERIENCER (PRO i1 PERSON "I"))  
(THEME (INF L1 LEAVE (AGENT i1)))))

Dealing with compound utterances is a more complex issue and not entirely relevant for the purposes needed here. If conjunctions are required they appear in the logical form as a type of operator. For example, the sentence *I wanted to leave but I lost the keys*, would have the logical form

(4.30) (ASSERT (BUT (PAST w1 WANT  
 (EXPERIENCER (PRO i1 PERSON "I"))  
 (THEME (INF L1 LEAVE (AGENT i1 ))))  
 (PAST L1 LOSE (AGENT (PRO i2 PERSON "I"))  
 (THEME (DEF/PL k1 KEY))))))

This logical form notation is sufficient to cover the language needs of the utterances that are used in the model presented here.

#### **4.8 A relevant domain for a model of natural language dialogue**

A major difficulty in modelling natural language is to decide on a domain which forms a focus for the language being modelled. A problem with modelling any kind of dialogue or conversation, presents the researcher with countless difficulties as the extent of knowledge and the possible inferences that can stem from this free ranging type of interaction can be very great and extremely difficult to build into a computer program. It would have been noted from the survey of previous models of language (2.2.1), that researchers limit their models to a particular domain which might be baseball, travel schedules, block worlds, or noughts and crosses in order to limit the possible inferences and the knowledge required by the system.

Limiting the model to a particular domain or task has particular advantages as it places a constraint on the extent and type of knowledge that is required to be represented and also the inferences that might need to be made, although this can still be very large. Using a limited domain does have its disadvantages, one of the major ones being that the models are not usually transferable to other domains. Thus,

SHRDLU (Winograd, 1972) might know much about the blocks world but would be totally lost with Clippinger's (1977) neurotic client. Power's. (1974) Mary and John might know something about bolts and opening doors but little about travel schedules. It might be argued that these programs were not built to deal with this range of issues which might be a valid argument but the major criticism is that these models of language production are too limited by their particular domains and that they could not be easily adapted to deal with others without radically altering their character.

A premise of this present work is that the belief and planning model presented here, does not have this limitation as it should be possible to give the model a different set of beliefs which should result in utterances relevant to those beliefs. However, it is necessary to have a relevant and an appropriate domain by which to demonstrate the workings of the model in the first instance and the particular domain chosen for this model is the type of interaction that might take place between a bookseller and a customer. The model has been applied to two other domains. The negotiations between management and union representatives and the interaction between a teacher and her students (see Appendix 6).

The interaction that takes place between a bookseller and a customer is a social relationship that many people in our society would be familiar with. Not least, because of the fact that trading normally occurs in a social context of law, trust and convention. For this reason it is likely to be associated in people's experience with a specific 'script' for buying and selling books and which has characteristics in common with other selling/purchasing transactions. It is a task oriented domain which can bring people into fairly close interaction with one another although each of them may not have known the other prior to the transaction. On the other hand, the sales-person and customer might be well known to each other because of regularity of contact but still go through the scenario of the 'book-selling script' as if they had only just met. The book-selling scenario is incidental as it could be that associated with the grocer's, the newsagent's or the garage etcetera.

It is a domain that can provide a source of dialogue from simple and brief exchanges to those of an extended and quite complex nature. Not only this, it is also a domain which lends itself to the specific purpose in hand which is to show that understanding natural language dialogue is also dependent on understanding the goal oriented and plan based nature of natural language.

There are three factors in the relationship being modelled. The customer, the bookseller and their knowledge about the artifacts relevant to the scenario. Customers have various, specific and general goals for buying books while booksellers have more prescribed goals for selling them. Each formulate plans and express these in language for achieving their separate and individual objectives but which combine to satisfy both participants. The ultimate goal of the bookseller is to sell books. The wise bookseller, like any good sales-person, might realize that this is best accomplished by satisfying the customer's needs and making the customer feel and believe that they have made the most appropriate choice. The more books she sells and the higher their price and mark-up, the greater her profit will be.

Some customers know what they want or they choose from the shelves and their sale can be made promptly and with the minimum of interaction or interference by the bookseller. The domain developed here is a scenario where a customer either accepts or requests help from the bookseller to assist them in their purchase and which necessarily involves both in an exchange of dialogue.

The bookseller has two options open to her in the way she approaches her task. She can attempt to force or persuade the customer to buy using the techniques of 'high pressure' selling or she can find out the customer's needs and seek to satisfy them. It is the latter method that is adopted here. The reason for this choice is that the latter method is considered to be more natural within a cooperative context and gives equal weight to the goals of both parties. The design of the model allows for either agent to have other sets of beliefs and goals and given these circumstances the former method could be adopted by the bookseller in another scenario with possibly very different outcomes.

Success for the bookseller is likely to depend on the questions she asks the customer, to elicit the knowledge required of the customer's needs. The bookseller has to formulate goals to achieve these objectives and adopt a plan for carrying them through. Therefore, relevant questions need to be asked by the bookseller as well as the making of suitable suggestions that are shaped in a manner most likely to satisfy the customer's goals as well as assist in achieving her own. The domain therefore, is a suitable one for exploring the nature of dialogue.

#### **4.9 The components of the model**

In this section a description of the components are given and how they function together. This will provide the reader with a general overview of the workings of the model and show how each stage of the process fits in with its counterparts. In the following chapter, the process will be simulated using an example dialogue scenario, utilising the notational forms and constructs identified and discussed in this chapter.

##### **4.9.1 The belief-sets**

Both participants in the model have a set of individual beliefs (general-belief-set GBS) that are personal to them and are related to the goals they wish to achieve. They also have a number of beliefs that they share with the other participant as well as having access to shared knowledge such as beliefs about the context and procedural knowledge of how plan-methods are used. Some distinction is made between what the agents in the model know and what they believe. Things that are known are factual things which either both agents know or only one of them knows. It is possible for beliefs to be true or false for either agent.

Both agents have goals which can be fairly general or specific depending on the scenario being modelled. For instance, in the sample scenario the customer's goals are specific in that she wishes to purchase a particular book whereas the bookseller's goals are more general, i.e. to sell any book and to please the customer. The agent who has

the more specific goal tends to maintain the overall initiative in the process although it is not necessarily this agent who initiates the dialogue.

Each agent has a goal which is made up of a number of concepts combined in certain relationships. This goal-belief is part of a larger set of beliefs which are related in various ways to the concepts of the goal-belief and also to beliefs relating to the context.

#### **4.9.2 Achieving goals and plan construction**

The initiating agent executes a plan operation to achieve the goal and a plan of this type is called **ACHIEVEGOAL**. Initially, a subsidiary operation called **CREATEGOALTREE** attached to **ACHIEVEGOAL** examines the propositions contained in the goal-belief and compares this set of propositions with the general-belief-set (GBS). Some propositions or elements of the proposition in the goal-belief might appear in the GBS because they are known to the agent while other elements might be marked as unknown. Any beliefs that relate to the goal-belief are identified by **CREATEGOALTREE**. It then creates a goal-tree of the propositions by which the goal is to be achieved. These propositions become sub-goals of the plan.

Propositions or parts of propositions may form a sub-goal in the agent's plan and indicate that a particular piece of information is required by an agent to fulfil a sub-goal. For instance, a plan for C's goal might take the following form:

**KNOWIF** bookseller has book XYZ

- **ASK** for yes or no type response

**KNOWINFO** book XYZ in paperback covers

- **ASK** for information whether book XYZ is available in papercovers

**KNOWIF** book XYZ cost £15 or less

- **ASK** for information on price of book

-**DECLARE** decision

-**BUY** book and **EXCHANGE-MONEY** for book

The precondition for the plan is that the agent does not possess the book and the effect of the successful fulfilment of the plan is that she does possess the book. The effects of the plan could change depending on the other agent's responses which could result in modification of the initial plan or even its abandonment. A more explicit description of the plan of C to achieve her goal is shown in Figure 4.1

The plan is made effective when it is translated into utterances. Each sub-goal of the plan realizes an intention of the agent and which culminates in an utterance. These together with the utterances of the other agent construct the dialogue. If the goal of C was to have the book at any cost, regardless of what price it was or what type of covers it was available in, this would have been indicated in the original set of beliefs from which the goal was formulated. In this event the sub-goals would be fewer as all C would need to do was ascertain from the bookseller whether she had the book for sale and indicate that she would buy it.

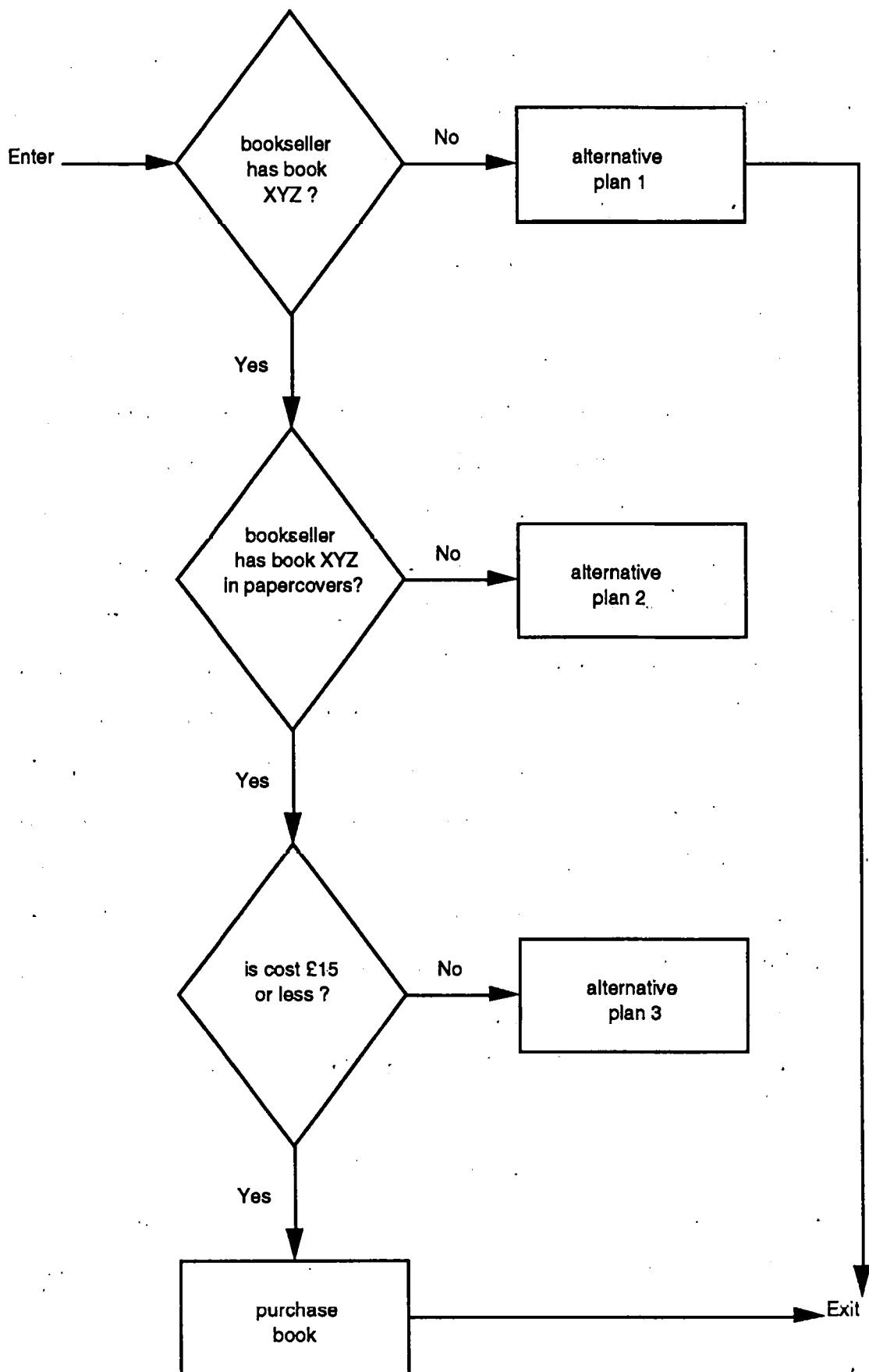
#### **4.9.3 Processing sub-goals**

If the set of propositions relating to a goal-belief contain undefined primitive predicates of the type HELP, WANT, BUY, HAVE and COST, these signify the steps that need to be taken for the goal to be realized. A particular problem relates to the order in which these subgoals should be realized and therefore is accomplished by ACHIEVEGOAL in a similar manner to the way a recursive function works. That is, each of the sub-goals are called or accomplished within the ACHIEVEGOAL process and before the original call to ACHIEVEGOAL can be completed.

Each sub-goal is achieved by plan-methods and other action operations. ACHIEVEGOAL operates on all the predicates within a goal-belief until they are achieved.

The way in which ACHIEVEGOAL is used is a fundamental characteristic of the model as it is this operation that controls the process until the agent's goals are achieved or given up. For example, if the sub-





**Figure 4.1 Customer's Plan**

goals contain the predicates WANT and BUY, each plan-method with the name of WANT and BUY are called in turn. Because of the nature of plan-methods and the selectional restrictions associated with them, a particular plan-method might not be able to achieve its individual goal immediately because additional knowledge is required before it can do this or further predicates associated with the goal-belief remain to be processed.

The presence of further predicates in the set of propositions is likely to signify that more information is required or needing to be processed. The WANT plan-method of this particular sub-goal might be called first and identified as having an object (it could be a state). This might be identified as a particular BOOK that is wanted. One of the selectional restrictions of the WANT plan-method is that whatever object is identified by the WANT plan-method should be POSSESSED. At this stage in the process the sub-goal WANT is tagged with a NOTYET flag, as the object of WANT is not yet possessed. At this point the WANT plan-method has achieved part of its objective but there are other plan-methods in the goal-belief waiting to be processed. The WANT plan-method is then held in abeyance while the BUY plan-method is called. Once again the object of the BUY plan-method is identified and discovered to be a particular BOOK with the title XYZ. A selectional restriction of the BUY plan-method is the action EXCHANGE which is required for the plan-method's successful prosecution. This similarly is tagged at this stage with the flag NOTYET. The BUY plan-method is then held over because ACHIEVEGOAL continues to process the remaining predicates.

The predicates of COST and HAVE are examined by ACHIEVEGOAL and it is noted by this operation that the object of WANT and BUY requires the properties signified by COST and HAVE, that is, a value of [£15] and a particular binding i.e. [papercovers]. Predicates of the type HAVE and COST indicate a particular kind of state possessed by objects and are defined in the agent's GBS. These are similar structures to plan-methods and also have selectional restrictions relating to their use.

In the initial operation of **ACHIEVEGOAL**, the information that the object of **WANT** and **BUY** is identified as being a specific book, namely **BOOKXYZ**. The price of this book and whether it has papercovers has been identified as being unknown. Consequently, **ACHIEVEGOAL** executes an **UTTERANCEPLAN** operation to obtain the required information.

#### **4.9.4 UTTERANCEPLAN**

An **UTTERANCEPLAN** operation constructs plans for the formation of utterances in order to realize the sub-goals associated with each agent's main goal. Plans are constructed one at a time and take place within the overall control procedure of **ACHIEVEGOAL**. That is, the sub-goals attached to each predicate node in the goal-tree govern what sort of utterance plan is to be constructed and are processed in turn. As each of the utterances are made, the recursive action of **ACHIEVEGOAL** unwinds and **UTTERANCEPLAN** operations process each of the nodes previously held in abeyance but only if utterances are required by these sub-goals. Some sub-goals may only require other actions like **BUY** requiring an **EXCHANGE** type action. It is possible though, that an utterance might be required by one of these associated actions in the realization of a sub-goal.

Utterance plans, as previously noted can be one of three kinds **DECLARE**, **ASK** and **COMMAND** and are cast as plan-methods. A sub-goal which is attached to a **~KNOWN** predicate automatically indicates an **ASK** type plan-method. Whether it is a **KNOWIF** type question that is required or a **KNOWINFO** depends on the elements contained in the proposition comprising the sub-goal.

A plan is constructed by **UTTERANCEPLAN** from the sub-goals associated with the original goal. That is, from the subgoals containing the predicates (e.g. **WANT**, **BUY**, **HAVE** and **COST**). These are constructed one at a time and in the order designated by the operation of **ACHIEVEGOAL**. For example, if the last predicate to be identified by **ACHIEVEGOAL** prior to **UTTERANCEPLAN** being initiated is **COST**, it relates to whether the object costs £15 or less. **UTTERANCEPLAN**

examines this sub-goal and because it is attached to a `~KNOWN` predicate this indicates to `UTTERANCEPLAN` that an `ASK` operation be initiated. Furthermore, information attached to the predicate `COST` would indicate that the range of an object's cost could vary and this would indicate to `ASK` that the plan-method `KNOWINFO` should be selected in this instance. This requires information from the other agent rather than a simple yes/no type response.

Having made a decision as to what kind of utterance is to be made `UTTERANCEPLAN` then invokes a frame with slots which will reflect the logical form of the utterance. This is called a `LOGFORM`. Some of its slots are filled by inheriting from the fillers of the `CONTEXTFRAMES` but the first three slots designate the utterance type, the tense of the utterance and its main action or object. This latter information is derived from the elements of the agent's sub-goal. Tense defaults to present tense (`PRES`) unless future (`FUT`) or past (`PAST`) is indicated in the sub-goals of the agent. `LOGFORM` refers to the frame in which the logical form of the utterance is formed and will be used when referring to this construct. The term 'logical form' is used when referring to the contents of this frame or when speaking generally about the forms of the agent's utterances.

`UTTERANCEPLAN` fills the first slot of the `LOGFORM` with the component that indicates what type of utterance it is to be. It could be a `Y/N QUERY` or `WH-QUERY` for an `ASK` type utterance or an `ASSERT` for a `DECLARE` type utterance. `UTTERANCEPLAN` then constructs a logical form for the rest of the planned utterance from the other concepts contained in the sub-goal being processed and also derives information from the `CONTEXTFRAMES`. Information from the `CONTEXTFRAMES` indicate what case slots need to be included in the logical form construction.

#### **4.9.5 CONTEXTFRAMES**

`CONTEXTFRAMES` are the constructs used to record the case information available from the context. They comprise the beliefs the agents have about the context

of the situation. These are not represented in the agent's GBSs directly but in frame-like structures of the slot and filler variety similar to the representation for plan-methods (cf 4.7). A full list of cases used in the model is given in Appendix 3 and the following is an example:

<b>CASE-NAME:</b>	AGENT
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	((SELF = I) (OTHER = YOU) (ANIMATE))
<b>ACTION/STATE:</b>	NIL
<b>SUBSIDIARY FUNCTIONS:</b>	NIL

What was said about representing beliefs about plan-methods in 4.7 can be said also about the representation of agent's beliefs about the context. Representing contextual beliefs as frame-like structures helps to capture succinctly, some of the knowledge that is associated with these type of belief objects. Cases have restrictions on who and what can fill a particular case role. Some roles or states indicate a state of affairs to exist while others indicate some action. Once again it has to be noted that these type of beliefs appear to be multi-dimensional and though they could be represented in a propositional format this does not do justice to their individual complexity. For the purposes of this model they are best represented as belief objects in frame-like structures that more specifically represent their salient characteristics.

Particular cases are known to the agents such as AGENT, BENEFICIARY, LOCATION, THEME etc., which knowledge is derived from the context of the situation the agents are in. Some of the slots for these cases are filled at the commencement of the dialogue and become part of the agent's knowledge configuration. Others are filled in as the dialogue develops and can also change in this process, therefore, the CONTEXTFRAME belief structures are dynamic structures. The changes in these dynamic structures are carried out by subsidiary functions carrying messages between the different belief objects as well as the operations used to

carry out the dialogue. For example between ACHIEVEGOAL, UTTERANCEPLAN, CONTEXTFRAMEs and PLAN-METHODs. Whereas some of the slots can be filled directly, because the knowledge relating to these cases is available from the context, fillers for other slots, such as the THEME slots can only be filled as each sub-goal is processed.

A slot can have more than one filler. For example, in the CONTEXTFRAME for AGENT, the IDENTITY FILLERS slot can have at least two fillers i.e. SELF and OTHER. The reason being that generally, when the agent is making an utterance they will view themselves as being the agent and will use the SELF restriction in the AGENT slot for constructing a logical form in which they themselves serve as the AGENT. On these occasions they will view the agent they are interacting with as the CO-AGENT and the IDENTITY FILLER in this slot will mark OTHER as the appropriate filler. A similar set of selective restrictions fill the IDENTITY FILLERS slot for the BENEFICIARY case, where the beneficiary indicated in an utterance could include either self, the other speaker or some other person. A full list of CONTEXTFRAMEs that are used in the model, along with their slot fillers, appear in Appendix 3. Definitions of these cases can be found in Appendix 4.

Once an utterance is made, ACHIEVEGOAL checks to see whether any further utterance needs to be made in the pursuit of the particular sub-goal being processed, or whether to await a response from the other agent. Depending on the decision, either a further utterance is made or a response is awaited from the other agent.

The logical form of the utterance of the speaking agent is displayed to the hearing agent and is identified by the other agent as requiring interpretation. An INTERPRET operation is made by the receiving agent and an analysis of the logical form of the speaker's utterance is carried out within the process of their own ACHIEVEGOAL operation. Initially, INTERPRET identifies the type of utterance made by the speaker as to whether it is a DECLARE, ASK or COMMAND type. Following identification of the type of utterance it is, INTERPRET processes the information in the remainder of the speaker's logical form. The way in which this processing is carried out is

dependent on what type of utterance it is. An ASK utterance of the type WH-QUERY will indicate to INTERPRET that the speaker is requiring information relating in some way to the remaining concepts displayed in the logical form.

The information in the logical form is processed and the hearer's ACHIEVEGOAL issues a DECLARE operation to provide information known to the hearer to be displayed to the first speaker. This is then displayed in a logical form to the agent who made the utterance. The original speaker then becomes the hearer and issues an INTERPRET operation to process the first hearer's response. This process continues until the dialogue achieves its objectives.

Information from responses results in their beliefs being updated with this new information so that the same question is not asked again. As the GBSs are updated the sub-goals are removed from the goal-trees and the next sub-goal initiated. More than one sub-goal can be removed from the tree at this stage for the reason that more than one sub-goal which initiated the utterance might have been achieved. This can be as a result of one agent providing more information than was originally requested by the other agent but in accordance with the second agent's goals.

The model presented here is based on four major operations and their subsidiary functions. To recap, these are ACHIEVEGOAL, UTTERANCEPLAN, LOGFORM and INTERPRET. These have been referred to and discussed as though they were single procedures but this is somewhat misleading. These procedures are in fact a number of operations that realize the objective indicated by the main procedure from which they take their name. Mental processes are complex and it is not helpful to identify these as being simple or singleton types of operation. The model seeks to explain the process of dialogue at a macro level and therefore does not set out to represent all the operations that comprise and support the major operations at a micro level.

Consequently, subsidiary operations employed by the major operations are assumed. Some of these operations may be as basic as GET, OBTAIN, SHOW, COMPILE, ADD, TAKE etc., and manipulate information for use by the major

operations. This approach has some psychological plausibility. Agents have some awareness of the major operations which are used to form utterances although they might not know or be able to explain how these work. Whilst we might have some awareness of achieving a goal or planning an utterance there are likely to be many tacit operations and functions that accompany this process that we are totally unaware of and that are carried out automatically. This model makes a distinction between the major operations used in utterance formation and the more tacit subsidiary operations that might underlie and support their formation and operation.

In the following chapter the process of the model is simulated with a sample dialogue and scenario.

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## **Chapter 5 - A trace through the process of dialogue - the model in operation**

Having described the major components and operations and given an overview of how the model achieves its objective it is necessary to examine the process by which an example scenario of dialogue is produced. Other subsidiary components and operations of the model will be explained in this chapter as and where they necessarily fit into the dialogue process.

The process is traced from the formulation of goal-trees of each of the agents through to the making of the individual utterances and to the achievement of goals and the completion of the chosen dialogue scenario.

The process at the beginning is complex because of the necessity of detailing each stage of the process for each agent. However, once the first cycle of the model has been completed, that is, one agent has made an initiating utterance and the other agent has made a response, it is not my intention to explain the same processes that operate similarly for the remaining cycles. This could become unnecessarily laborious for the reader. Further detailed explanation will be given only where this serves to clarify a particular aspect of the model or its process.

Following the explanation of the first cycle of dialogue, explanation of the remaining cycles will be in an abbreviated form. This is accomplished simply by invoking the names of the processes that have previously been explained in detail and without delineating their specific operations each time. An advantage of dealing with the process in this way is that the close juxtaposition of each agent's utterances, without the intervening explanation, will afford a more succinct view of the remaining cycles and show how the logical forms of each agent's utterance, derives from their individual beliefs and goals, dovetailing together to achieve a dialogue in which both agents realize their goals.

## 5.1 A note about research methodology

Bundy et al (1984: 146) have suggested a research strategy for AI which has been adopted as a basis for this work. They suggest that the researcher initially thinks of a scenario or a sample of output that exhibits the ability they want the computer to model. In vision this might be the recognition of a scene or in mathematics it might be a proof and in natural language a sample dialogue. After this initial stage, a hypothesis is made as to what processes might be involved in achieving the scenario.

A third stage is to think of further scenarios to see whether the proposed program could cope with them and which are used to refine, generalize, extend and debug the initial program. The fourth stage they suggest is that when satisfied and the proposed program is stable, the researcher should choose a programming language that closely fits the need and implement the program. This program then needs to be run on further scenarios that haven't previously been considered and is modified until it is 'robust'. The last stage is to describe the program by using a language that is independent of the particular implementation.

Generally, this methodology has been adopted for this work with some variation in the stages. A dialogue scenario has been selected from a particular domain (see below & 4.9). A hypothesis has been made as to how this particular piece of dialogue might be achieved and what processes might be involved (Chapter 3). This is described by using a language that is independent of the particular programming implementation for the model and which has been the purpose of the preceding chapter and this one and which provides an animated description of the model as it processes the chosen dialogue scenario.

Whilst it would be pleasing to produce a working computer program of the model this is not the main objective. The prime purpose is to derive a theory of natural language dialogue viewing it in AI terms as a process and using some of the constraints of AI tools and techniques to guide theory construction. Following the research strategy outlined above, the chosen scenario to be modelled is a dialogue between a bookseller or shop assistant and a customer. The model has also been

applied to two other scenarios, those of a union/management negotiation and a teacher/pupil situation. These applications are to be found in Appendix 6 and are referred to in the concluding chapter evaluating the model.

The bookseller/customer dialogue to be modelled is as follows:

Example Scenario - A customer asks the bookseller for a specific title.

- B. Can I help you?  
C. Yes Please.  
Have you got any copies of XYZ?  
B. Yes, I have them, both in papercovers and hardcovers.  
C. How much is the papercover copy?  
B. £15.  
C. I'll take it.

Though on the surface a fairly simple, and uncomplicated piece of dialogue it poses a number of language problems, such as questions, answers, definite reference, anaphora, substitution, ellipsis, and turn-taking to name but some of them. The purpose of this chapter is to describe in detail the way in which the model produces the sample piece of dialogue.

A useful metaphor to explain what is being attempted here is to imagine that the knowledge configurations of an agent can be likened to a movie film made up of hundreds of individual picture frames. During editing, a film can be stopped and each frame examined individually. In this state, changes between one frame and the next in the sequence appear to be imperceptible.

What I am trying to describe in this chapter is a similar scenario. It is as if the knowledge configurations of two agents who are interacting together have suddenly been frozen at a particular point in time and then allowed to move on slowly providing an opportunity to examine the on-going process in some detail. It is as though a snapshot is taken of the knowledge configurations belonging to two agents which allow us to examine their beliefs and goals at the particular moment just prior to the

commencement of the sample scenario dialogue. That is, knowledge configurations that contain some general beliefs relevant to the context and task in hand, goals to achieve some objective, and some plans and plan-method functions for achieving those goals.

## **5.2 A process simulation of the model**

In this section the operations of the model are simulated and show how the scenario dialogue is produced. It is necessary to follow the procedures of the model through in some detail to see the way in which each agent's goals are achieved and how utterances made by both agents contribute to this dialogue and to the achievement of individual goals. The dialogue is dealt with in three cycles. That is, a move by one agent and the response to it are viewed as a cycle. No particular importance is attached to these cycles and they are differentiated only for ease of description.

### **5.2.1 The first cycle of dialogue**

1.     B     Can I help you?
2.     C     Yes Please!
3.           Have you got any copies of XYZ?

Initially, goals have to be attributed to both agents and for this particular scenario the customer B's goals are:

B wants to sell any books of high value to C. In a propositional representation this is:

(SELL, BOOKSELLER, BOOK) & (WANT, BOOKSELLER, a, b)  
& ((BUY, CUSTOMER, BOOK[S]) = a) & ((HIGHVAL, BOOK[S]) = b)

C's goals are more specific than B's goals:

C wants a book with title XYZ in paperback and will pay up to £15 for it, to B.

(HAVE, CUSTOMER, BOOKXYZ) & (WANT, CUSTOMER, BOOKXYZ)  
 & (IF a, b, c (BUY, CUSTOMER, BOOKXYZ)  
     &((HAVE, BOOKSELLER, BOOKXYZ) = a)  
     & ((PAPERBACK, BOOKXYZ) = b)  
     & ((VALUE £15, BOOKXYZ) = c)

As C's goals are the more specific of the two, the major initiative for dialogue comes from C. C has a specific goal to achieve whereas B has more general goals and does not know at the initial stage what C has in mind. Though B has a more general goal overall this does not mean to say B's plan for responding to C's request will be more simple. In some respects B has a greater task on hand as she needs to find out a considerable amount of information, if she is going to achieve her goal of selling books of high value without knowing C's objective.

It will be seen that B's plan can be quite complicated. For B to achieve her goal she needs to have the following information. She wants to know whether C requires any help and what she might want. Her general belief set (GBS) at this stage indicates that this information is not known. Furthermore, she does not know that C does not possess a particular book. Although B is not aware of what C might know about a particular book she is aware of the books she has available for sale. Therefore, whether the knowledge about a particular book C might or might not be aware of, appears in B's GBS as specific propositions but which are identified as not being known.

For C to achieve her goal she needs to know answers to the following questions. Whether the bookseller has XYZ in stock and for sale; whether it is available in paperback and whether its price is either £15 or less. The belief-set at this stage, relevant to achieving this goal is constituted mostly of what she does not know. She does not know whether the bookseller has the book, neither does she know what price it might be and whether it is within the price range she has set herself. Nor does she know whether it is available in paperback which might have some bearing on its price.

The propositions relating to these characteristics of the goal-beliefs appear in her GBS and are marked as being KNOWN or ~KNOWN. An agent may want a book without knowing the price of a book and without even thinking about its value or cost. At this stage the agent may not know the cost of the book, only that it will have a cost. At a later stage, when there is a firmer intention to purchase the book, the cost of it may then become more prominent or important to the agent. This is not the place to discuss such ontological issues of knowledge and belief. What is important for the purposes of this model is that a goal is formed from a set of beliefs and the agent having formulated a goal draws certain conclusions about the knowledge they do not possess but need to possess if they are to achieve a particular goal.

The beliefs in B's GBS relevant to her goal are:

(~KNOW, BOOKSELLER) & (IF a )  
 & ((WANTS, CUSTOMER, HELP) = a)  
 (~KNOW, BOOKSELLER) & (IF a, b, c, d)  
     & ((KNOW, CUSTOMER) = a )  
     & (PAPEROVERS, BOOKXYZ) = b )  
     & ( HARDCOVER, BOOKXYZ) = c)  
     & (VALUE£15, BOOKXYZ) = d))

The beliefs in C's GBS relevant to her goal are:

(~KNOW, CUSTOMER) & (IF a, b, c, )  
     & ((HAVE, BOOKSELLER, BOOKXYZ) = a)  
     & ((PAPEROVERS, BOOKXYZ) = b)  
     & ((VALUE£15, BOOKXYZ) = c)

### 5.2.2 Goal achievement

Immediately prior to the commencement of the scenario dialogue the constellation of beliefs belonging to B and C are as set out above. The beliefs that comprise their goals and those related beliefs from their GBSs together form the specific-belief-sets (SBSs) for the achievement of their goals. At the commencement of the dialogue each

agent initiates an operation to achieve their respective goals. This operation is called **ACHIEVEGOAL** and is the control process by which goals are achieved from the time they are initiated to the stage where they are either achieved or abandoned. It is an operation that acts recursively (4.9.3). That is, a goal might be initiated but because it cannot be carried out immediately, it is held in abeyance until it can be. A reason for a goal not to be carried out immediately might be because other sub-goals have to be fulfilled first and the initial goal's successful fulfilment is dependent on the sub-goals being filled in. **ACHIEVEGOAL**, though referred to as a single operation consists of a number of operations but which operate within the overall function of achieving the goal.

A subsidiary operation attached to **ACHIEVEGOAL** is **CREATEGOALTREE** which is a planning operation whose function it is to examine the propositions contained in the goal-belief and to compare these with those in the GBS which are in anyway related to achieving the goal. Those that are related are added to the goal-belief propositions and compile the SBS. **ACHIEVEGOAL** then constructs a planning goal-tree from the propositions and predicates of the SBS. The goal-trees for the bookseller and customer are shown in Figures 5.1 and 5.2 respectively.

Having constructed a goal-tree **CREATEGOALTREE** returns the tree to **ACHIEVEGOAL** which sets about the process of working through the sub-goals of the plan. **ACHIEVEGOAL** examines the predicate nodes in the tree working from the root node and then left to right across the tree, seeking to fulfil the individual sub-goals. The process will be traced for both B's and C's achieve-goal operations.

Before proceeding further, it may be noted that nothing has yet been said as to who initiates the conversation in this particular dialogue scenario and this needs to be clarified. Who starts a dialogue is a characteristic which cannot be entirely captured by the model because some aspects of dialogue are governed by contextual and non-verbal factors as well as the individual goals and purposes of agents. Even so, in the piece of dialogue that is being modelled here, specific goals have been attributed to both agents and it is possible that the goals which motivate the bookseller might

predispose her to speak first, especially if the customer approaches her and gives a non-verbal indication requesting help. This is the scenario indicated by the goals attributed to B and C and to which the dialogue adheres.

### **5.2.3 The bookseller's execution of ACHIEVEGOAL**

B's main goal is (SOLD, BOOK[S]), that is, to be in a state of having sold a book or several of them. ACHIEVEGOAL requires the first component of a proposition to be a predicate of some kind. This predicate is fundamental and governs how the arguments following it are to be used. The predicate in this instance is SOLD which is a state that the bookseller would like to achieve for either one of her books or many of them. SOLD is a state which appears in B's GBS as a proposition and is defined as follows:

(SOLD, STATE)

For B's sub-goal to be achieved the proposition (SOLD, BOOK) would have to be present in B's GBS. ACHIEVEGOAL identifies that this goal has not been achieved by using a CHECK operation to ensure that no belief registering this state of affairs exists in her GBS. If the GBS contained this belief then the goal-state would be considered as having been achieved and the process would be completed without any dialogue taking place. A consequence of the belief not being present in the GBS, is that this root goal node is flagged with a NOTYET achieved marker and the goal is held in abeyance while the next sub-goal is processed.

Moving down the goal-tree ACHIEVEGOAL identifies the next sub-goal. In this instance it is the predicate WANT which is a plan-method. ACHIEVEGOAL examines the WANT plan-method to view what selectional restrictions might be attached to it and also to see whether this sub-goal can be achieved. The WANT plan-method is:



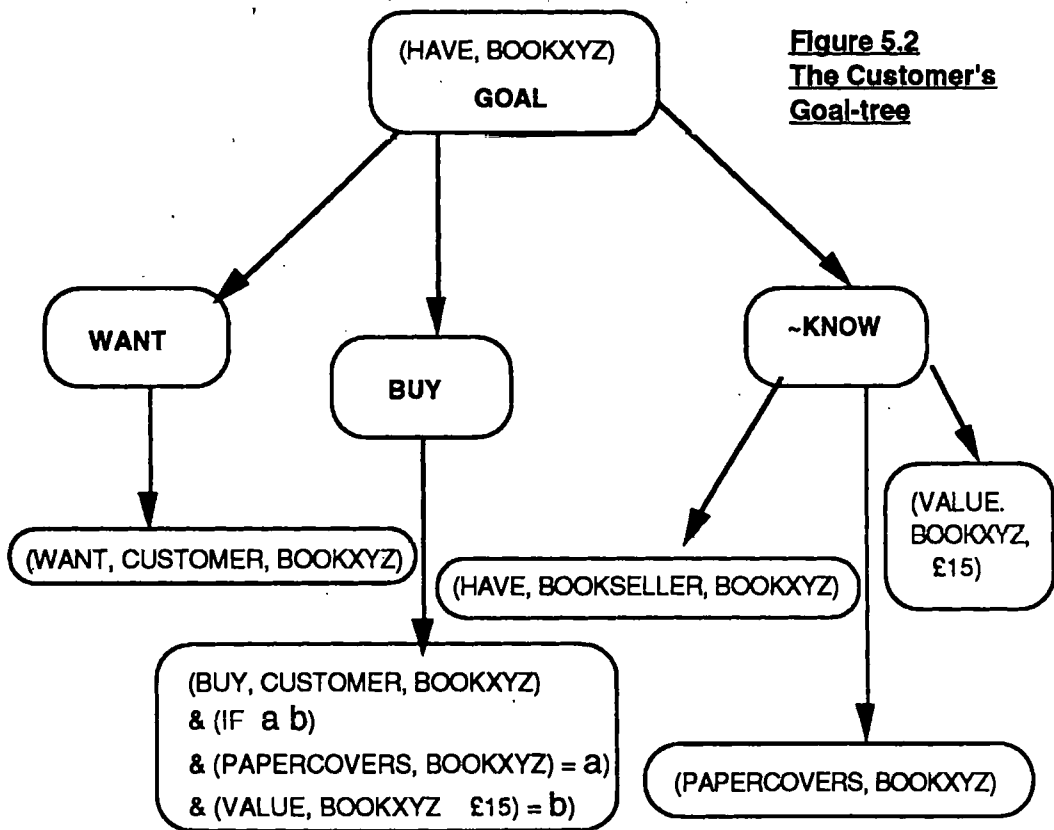
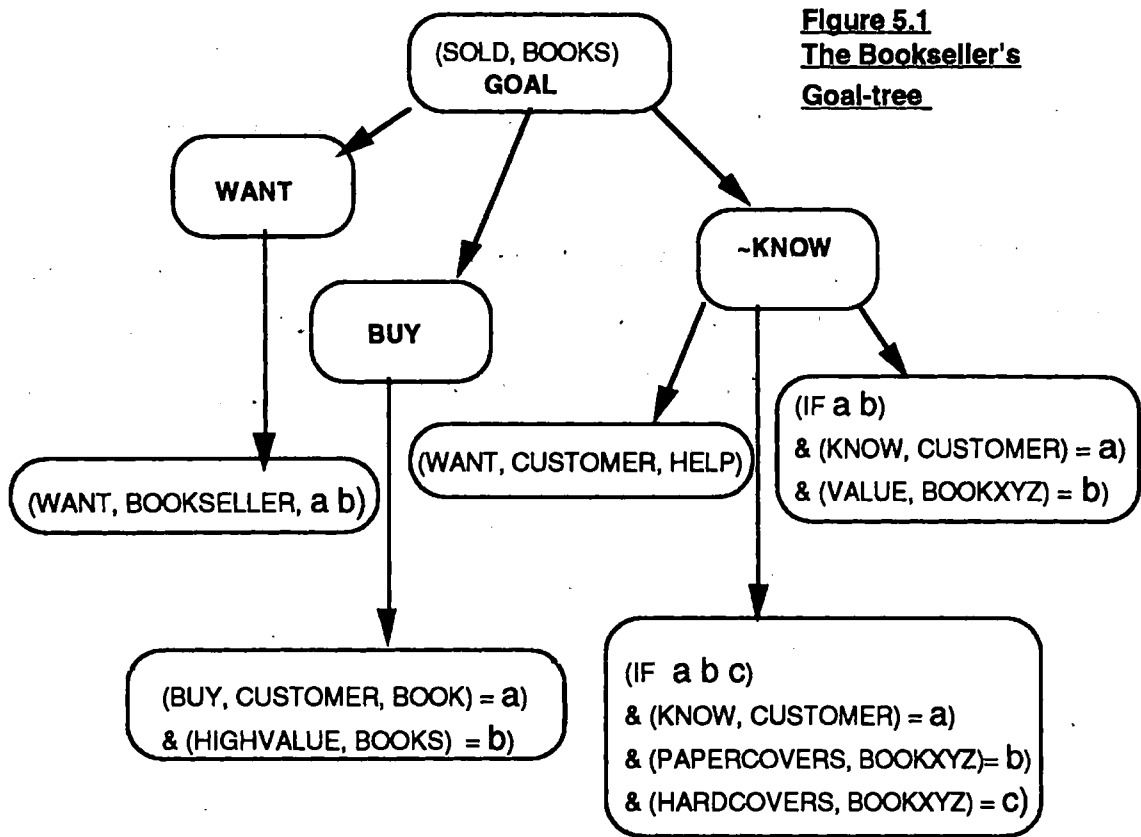
**NAME:** WANT  
**OBJECT:** (a b)  
**FROM:** CUSTOMER  
**TO:** BOOKSELLER  
**ACTION:** ((POSSESS (OBJECT)(STATE))(SATISFIED (STATE)))

One of the slots for the WANT plan-method indicate that if this is to be carried out successfully the wanted object must be either POSSESSED or the state be SATISFIED. ACHIEVEGOAL identifies that this sub-goal contains. propositions that require further information and therefore cannot be achieved immediately. Consequently, the node WANT is flagged with a NOTYET marker and this marker is placed in the ACTION slot of the plan-method.

**NAME:** WANT  
**OBJECT:** (a b)  
**FROM:** CUSTOMER  
**TO:** BOOKSELLER  
**ACTION:** (POSSESS-STATE (NOTYET))

The other slots of the WANT plan-method are also filled with the arguments from the sub-goal. The OBJECT slot is filled with the markers a and b. These refer to other sub-goals in the goal tree that still await processing and require further information. The second argument of the sub-goal, i.e. BOOKSELLER, fills the TO slot as this is the agent who wants to be in the state of possession. The FROM slot defaults to C, the other agent in the dialogue scenario. This sub-goal and its plan-method are also held over while the next sub-goal is processed.

ACHIEVEGOAL moves on to examine the predicate node BUY and its sub-goal ((BUY, CUSTOMER, BOOK) = a) & ((HIGHVAL, BOOK[S]) = b). ACHIEVEGOAL identifies that the sub-goals attached to the BUY node are related to an earlier sub-goal which was marked as being NOTYET achieved. ACHIEVEGOAL knows from the GBS that there are no knowledge items contained there that indicate that this next sub-goal has been achieved. Consequently, the predicate node BUY is marked with a NOTYET flag and is placed in the action slot of the BUY plan-method



which would have been activated at this point. This sub-goal and its associated plan-method are also held over to be completed later.

In this operation the slots of the BUY plan-method are filled in with elements from the sub-goal:

**NAME:** BUY  
**OBJECT:** (HIGHVALUE, BOOKS)  
**FROM:** BOOKSELLER  
**TO:** CUSTOMER  
**ACTION:** ((EXCHANGE (MONEY FOR OBJECT)) NOTYET)

ACHIEVEGOAL then examines the remaining predicate ~KNOW which indicates that several elements of knowledge are not known and need to be known if the two previous sub-goals are to be achieved. The propositions not known to B are:

(WANTS, CUSTOMER, HELP)  
(IF a, b, c) & ((KNOW, CUSTOMER) = a)  
& ((PAPEROVERS, BOOKXYZ) = b)  
&((HARDCOVERS, BOOKXYZ) = c))  
(IF a, b) & ((KNOW, CUSTOMER) = a) &(VALUE, BOOKXYZ) = b))

No further predicates remain to be processed at this stage, therefore ACHIEVEGOAL executes an operation to construct an utterance. This is called UTTERANCEPLAN and operates on the three sub-goals of the ~KNOWN node in turn, again working from left to right, constructing an utterance plan for each as is required. This operation will be described later. First it is necessary to outline the execution of C's ACHIEVEGOAL operation.

#### **5.2.4 The customer's execution of ACHIEVEGOAL**

A similar operation as described above for B is executed by C's ACHIEVEGOAL operation. The goal-tree is constructed by CREATEGOALTREE in a similar manner and from the SBS composed of goal-belief propositions and beliefs within C's GBS.

Some of the predicate nodes happen to be similar to those of B and occur because of the similarities for both agents of the context in which the dialogue is taking place. Though the predicate nodes are similar, this is only a surface similarity as the sub-goals associated with the predicates are different and are the most strategic elements in this process. ACHIEVEGOAL examines each node of the tree in turn, moving from the top and then down and left to right in processing the predicate nodes and sub-goals.

The root node represents C's main goal which is, (HAVE, BOOKXYZ), that is, to possess a certain book with the title XYZ. Like B's main goal the predicate of this proposition is a state that C would like to achieve, which is to possess a book with a particular title. Some states are defined as beliefs and appear in the GBSs of the agents while other states are defined as plan-method-like objects. This is for the reason that some states, like HAVE, can have an action component included in their definition as well as a 'state' sense component. ACHIEVEGOAL uses a CHECK operation to examine the GBS and returns a product indicating that this goal is not yet achieved because no representation of it appears in the GBS. In this process the HAVE plan-method is activated and its relevant slots filled with elements from the goal. The FROM and TO slots are filled with SELF or C or the other agent in the dialogue and which indicate the direction in which the object is expected to change in POSSESSion. The node of the goal-tree is marked with a NOTYET flag and this is placed in the ACTION slot of the HAVE plan-method. The sub-goal is held over for later processing.

NAME:	HAVE
OBJECT:	BOOKXYZ
FROM:	BOOKSELLER
TO:	CUSTOMER
ACTION:	((POSSESS (STATE)) NOTYET)

The next node to be examined is the predicate WANT and the sub-goal attached to this is (WANT, CUSTOMER, BOOKXYZ). ACHIEVEGOAL examines the WANT

plan-method to view what selectional restrictions might be attached to it and also to see whether this sub-goal can be achieved. One of the slots for the WANT plan-method indicate that if this is to be carried out successfully the wanted object must be POSSESSED or SATISFIED. The WANT plan-method is activated and its slots filled with elements from the sub-goal. In this instance an OBJECT is the focus of the WANT plan-method and therefore the ACTION slot defaults to the options of POSSESS-OBJECT.

NAME:	WANT
OBJECT:	BOOKXYZ
FROM:	BOOKSELLER
TO:	CUSTOMER
ACTION:	(POSSESS-OBJECT (NOTYET))

ACHIEVEGOAL uses a CHECK operation to examine the GBS and finds that the object in question is not POSSESSED and so the node WANT is flagged with a NOTYET marker which is placed in the ACTION slot of the plan-method alongside the element that will be activated as an action or state at a later stage. This sub-goal is held over while the next sub-goal is processed.

ACHIEVEGOAL moves on to examine the predicate node BUY and its sub-goal (BUY, CUSTOMER, BOOKXYZ). Other propositions form part of this sub-goal. The customer will buy the book given certain conditions. That is, providing the book is in papercovers and is £15. It examines the BUY plan-method and finds that a selectional restriction on BUY is the further plan-method operation EXCHANGE.

Another slot of the BUY plan-method indicates to ACHIEVEGOAL that an object is involved and this is identified as being the BOOKXYZ of this sub-goal as well as that of the previous sub-goals. ACHIEVEGOAL already has a record that this object has been dealt with in the processing of an earlier sub-goal which was marked as being NOTYET achieved. Consequently, the predicate BUY is marked with a NOTYET flag and the ACTION slot of the plan-method is flagged accordingly.

**NAME:** BUY  
**OBJECT:** BOOKXYZ  
**FROM:** BOOKSELLER  
**TO:** CUSTOMER  
**ACTION:** ((EXCHANGE (MONEY FOR OBJECT)) NOTYET)

The sub-goal is held over to be completed later. ACHIEVEGOAL then examines the remaining predicate ~KNOW which indicates that three elements of knowledge are not known and need to be known if the two previous sub-goals are to be achieved. The propositions not known to the customer are:

(HAVE, BOOKSELLER, BOOKXYZ)  
(PAPEROVERS, BOOKXYZ)  
(VALUE£15, BOOKXYZ)

No further nodes remain to be processed at this stage therefore ACHIEVEGOAL executes an operation to construct an utterance to achieve the first sub-goal attached to the ~KNOW node. UTTERANCEPLAN processes these sub-goals from left to right and in the order they are attached to the predicate node.

Before describing UTTERANCEPLAN for C it is necessary to describe the same operation for B first.

### **5.2.5 The bookseller's execution of UTTERANCEPLAN**

The first sub-goal on which B's operation of UTTERANCEPLAN works is (WANT, CUSTOMER, HELP). The node to which this sub-goal is attached is a ~KNOW predicate which is also defined as a plan-method. The ~KNOW plan-method is called and elements from the sub-goal are used to fill the slots of the ~KNOW plan-method. In the processing of this sub-goal two other plan-methods are activated, namely WANT and HELP so at this initial stage three plan-methods have been activated.

**NAME:** ~KNOW  
**OBJECT:** HELP  
**FROM:** BOOKSELLER  
**TO:** CUSTOMER  
**ACTION:** (ASK (KNOWIF-QUESTION) (KNOWINFO-QUESTION))

**NAME:** WANT  
**OBJECT:** HELP  
**FROM:** BOOKSELLER  
**TO:** CUSTOMER  
**ACTION:** ASK KNOWIF-QUESTION

**NAME:** HELP  
**OBJECT:** NIL  
**FROM:** BOOKSELLER  
**TO:** CUSTOMER  
**ACTION:** OFFER-ASSISTANCE

The slots of the WANT plan-method are filled from elements in the sub-goal. The predicate WANT indicates that some object or state needs to be POSSESSED or SATISFIED and that this is related to another element in the sub-goal. This is the element HELP which can be either a state or an action. It is defined for both agents as a plan-method but how it is used depends on the selectional restrictions governing this particular plan-method. Its position within the proposition of the sub-goal indicates to UTTERANCEPLAN that it is a state that is required by C in this instance. The given information in this sub-goal is that of CUSTOMER and indicates to B which agent is to benefit from the state of HELP. The information that is not known to her is whether C wants help, (WANTS, CUSTOMER, HELP), the answer to which can be satisfied by a yes or no type response. The OBJECT that is wanted then, is the state HELP. The CUSTOMER wants this so the TO slot in the plan-method, which indicates the direction in which the help is to be pointed, is filled with C. The FROM slot defaults to B, she being the other agent in the dialogue and the provider of help.

The slots of the HELP plan-method are also filled. The object slot defaults to nil as there is no object in this instance. The TO slot is filled with C as this is the direction to which the HELP needs to be directed as indicated in the sub-goal. Furthermore, because C fills the TO slot this indicates that the HELP should be offered by B rather

than requested and is identified in the ACTION slot of this plan-method. Consequently, the OFFER-ASSISTANCE plan-method is also activated:

**NAME:** OFFER-ASSISTANCE  
**OBJECT:** HELP  
**FROM:** BOOKSELLER  
**TO:** CUSTOMER  
**ACTION:** (ASK KNOWIF-QUESTION (MOD/AUXpossib. "CAN"))

UTTERANCEPLAN takes information from the ~KNOW plan-method which indicates that the object HELP is required and that either a KNOWIF or a KNOWINFO type plan is required to obtain this HELP. UTTERANCEPLAN also examines the other plan-methods that have been activated with this sub-goal and obtains the information from the WANT plan-method that an ASK KNOWIF type of utterance will best achieve this sub-goal. Examination of the HELP plan-method indicates that HELP should be offered in this instance and the action slot on the OFFER-ASSISTANCE plan-method confirms that an ASK KNOWIF type of question should be planned for. UTTERANCEPLAN thus obtains the information from several sources, two of which are more specific than the other, that an ASK KNOWIF type of utterance is required. UTTERANCEPLAN can now commence an utterance form. The ASK KNOWIF type of question indicates that a yes/no type response is required and which is designated in the options of the action slot of the ~KNOW plan-method.

B does not know whether C can select the book she wants from stock on display or whether she wants help from B. The model assumes that the customer has signalled in a non-verbal manner that help by way of communication might be required from the bookseller.

Following UTTERANCEPLAN's processing of the sub-goal a subsidiary function of UTTERANCEPLAN called COMPILECONTEXT is called to fill the slots of the CONTEXTFRAMEs for later processing by UTTERANCEPLAN. Each agent takes the AGENT case when they are making the utterance and views the other agent as the



CO-AGENT. Therefore a CONTEXTFRAME for AGENT is created with the option SELF selected, and one for CO-AGENT with the option OTHER selected, both for later processing and use in the LOGFORM.

<b>CASE-NAME:</b>	AGENT
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	((SELF = (PRO PERSON "I")) (OTHER = (PRO PERSON "YOU", "HE", "SHE", "IT" "THEY", "THEM") (ANIMATE)))
<b>ACTION/STATE:</b>	((INTERPRET ("I" = "YOU") ("YOU" = "I")("HE", "SHE", "IT" = ?) ("THEY", "THEM" = ?)))
<b>SUBSIDIARY FUNCTIONS:</b>	NIL
 <b>CASE-NAME:</b>	 CO-AGENT
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	((SELF = (PRO PERSON "I")) (OTHER = (PRO PERSON "YOU", "HE", "SHE", "IT" "THEY", "THEM") (ANIMATE)))
<b>ACTION/STATE:</b>	((INTERPRET ("I" = "YOU") ("YOU" = "I")("HE", "SHE", "IT" = ?) ("THEY", "THEM" = ?)))
<b>SUBSIDIARY FUNCTIONS:</b>	NIL

Another element in the sub-goal is HELP which has previously been identified in this instance, as being a state. This element, and the information attached to the plan-methods already activated in relation to HELP, point to the necessity of some beneficiary being the recipient of this. Thus, a CONTEXTFRAME for BENEFICIARY is activated and the IDENTITY-FILLERS slot of this CONTEXTFRAME identifies OTHER rather than SELF as being the agent to benefit from the bookseller's assistance.

<b>CASE-NAME:</b>	BENEFICIARY
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	((SELF = (PRO PERSON "I")) (OTHER = (PRO PERSON "YOU", "HE", "SHE", "IT" "THEY", "THEM") (ANIMATE)))
<b>ACTION/STATE:</b>	((INTERPRET ("I" = "YOU") ("YOU" = "I") ("HE", "SHE", "IT" = ?) ("THEY", "THEM" = ?)))
<b>SUBSIDIARY FUNCTIONS:</b>	NIL

COMPILECONTEXT also compiles any other CONTEXTFRAMEs required by the context of the dialogue scenario and obtains this information from the GBS, sub-goal beliefs or plan-methods that have already been activated. The other CONTEXTFRAMEs required by B for this utterance are:

**CASE-NAME:** THEME  
**IDENTITY-FILLERS:** HELP  
**RESTRICTIONS:** SUBGOAL-ELEMENT  
**ACTION/STATE:** ((INTERPRET ("I" = "YOU")  
("YOU" = "I")("HE", "SHE", "IT" = ?)  
("THEY", "THEM" = ?)))  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** TO-LOCATION  
**IDENTITY-FILLERS:** SELF OTHER  
**RESTRICTIONS:** ANIMATE  
**ACTION/STATE:** TO-CUSTOMER  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** FROM-LOCATION  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ANIMATE,  
**ACTION/STATE:** FROM-BOOKSELLER  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** AT-POSSESSION  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ANIMATE  
**ACTION/STATE:** WITH-BOOKSELLER  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** TO-POSSESSION  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ANIMATE  
**ACTION/STATE:** TO-YOU  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** FROM-POSSESSION  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ANIMATE  
**ACTION/STATE:** FROM-SELF  
**SUBSIDIARY FUNCTIONS:** NIL

Working with the information that an ASK plan is being formed, UTTERANCEPLAN selects a KNOWIF type ASK plan-method, that is, a Y/N

QUERY. This is identified as being a required option of an ASK plan-method from the ACTION slot of the previously activated OFFER-ASSISTANCE plan-method.

<b>NAME:</b>	ASK
<b>OBJECT:</b>	NIL
<b>FROM:</b>	BOOKSELLER
<b>TO:</b>	CUSTOMER
<b>ACTION:</b>	((QUESTION ((ASK (KNOWIF-QUESTION = Y/N QUERY)) (ASK(KNOWINFO-QUESTION WH-QUERY))))

Having completed this operation UTTERANCEPLAN invokes a LOGFORM and places the flag Y/N QUERY in this frame as its first construct. This is the first slot of the LOGFORM for the utterance being constructed. UTTERANCEPLAN then utilises information from the CONTEXTFRAMEs to construct the rest of the LOGFORM. Before looking at how CONTEXTFRAME is used, C's operation of UTTERANCEPLAN will be explained.

### 5.2.6 The customer's execution of UTTERANCEPLAN

A limitation of a linear process model of dialogue is that it does not capture the parallel processing and near simultaneous production of dialogue which is an important characteristic of dialogue. Dialogue processes, are likely to operate simultaneously for both agents and this factor must not be forgotten. Whilst it may be possible for C to start her utterance before receiving B's offer of assistance, in this scenario B speaks first. Therefore, the major operations of each of the agents are described in turn and latterly it is shown how they cohere to produce a cohesive dialogue.

The description follows a path which describes how each agent forms their initial subgoals but the reader should bear in mind the caveat that C in this instance does not start to form her utterance until B has made her offer of assistance. However, she could have been forming a plan for her utterance either prior to, during or after B's initial utterance.

C's first sub-goal on which UTTERANCEPLAN focuses is (HAVE, BOOKSELLER, BOOKXYZ). This is attached to a ~KNOW predicate and therefore the ~KNOW plan-method is activated.

<b>NAME:</b>	~KNOW
<b>OBJECT:</b>	BOOKXYZ
<b>FROM:</b>	BOOKSELLER
<b>TO:</b>	CUSTOMER
<b>ACTION:</b>	ASK (KNOWIF-QUESTION, KNOWINFO-QUESTION)

The slots of this plan-method are filled with elements from the sub-goal being processed. The second argument of the sub-goal which is BOOKSELLER fills the FROM slot as this indicates where the information required is to come from. The TO slot defaults to C or SELF as this is the agent requiring the information. The OBJECT slot is filled with the third argument from the sub-goal, this being the object which is the focus of the information request. The ACTION slot on this plan-method indicates that a KNOWIF or a KNOWINFO question is a possibility. UTTERANCEPLAN continues to process the sub-goal and in doing so a HAVE plan-method is activated.

<b>NAME:</b>	HAVE
<b>OBJECT:</b>	BOOKXYZ
<b>FROM:</b>	BOOKSELLER
<b>TO:</b>	CUSTOMER
<b>ACTION:</b>	(POSSESS (STATE))

The slots of this plan-method are then filled by UTTERANCEPLAN. The OBJECT slot is filled with the third argument of the sub-goal, namely BOOKXYZ; the FROM slot with the second argument of the sub-goal, that is BOOKSELLER, and the TO slot defaults to C or SELF as this is a sub-goal belonging to C.

UTTERANCEPLAN then examines the ACTION slots of both the ~KNOW and HAVE plan-methods. The ACTION slot of the HAVE plan-method indicates that a POSSESS type of STATE is required which is related to the OBJECT and the BOOKSELLER components of the plan-method. This information, combined with the

filler of the ACTION slot of the ~KNOW plan-method, indicates that an ASK type of question should be made to obtain this information. In this instance either a KNOWIF or a KNOWINFO ASK plan-method will meet the objective and the first option is selected, that is, a KNOWIF type of ASK plan-method. This information is obtained from the activation of an ASK plan-method.

<b>NAME:</b>	ASK
<b>OBJECT:</b>	NIL
<b>FROM:</b>	BOOKSELLER
<b>TO:</b>	CUSTOMER
<b>ACTION:</b>	((QUESTION ((ASK (KNOWIF-QUESTION = Y/N QUERY)) (ASK(KNOWINFO-QUESTION WH-QUERY)))

UTTERANCEPLAN has identified the requirement for a yes/no type response in this instance. The information that C is after, is whether a specific book is available for sale from B. All that is required by the agent wanting this information is a signal indicating yes or no. UTTERANCEPLAN uses this information in the construction of its plan and decides on an ASK/KNOWIF plan-method. Having completed this operation UTTERANCEPLAN invokes a LOGFORM and places the flag Y/N-QUERY in this form as its first construct. Before describing how the rest of the logical form of the utterance is compiled it is necessary to describe C's COMPILECONTEXT operation.

This is a similar process to that described for B's CONTEXTFRAMEs. A number of CONTEXTFRAMEs required by the context are activated and their slots filled. The CONTEXTFRAMEs required by the the context and for use by C in this instance are:

<b>CASE-NAME:</b>	AGENT
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	((SELF = (PRO PERSON "I")) (OTHER= (PRO PERSON " YOU", "HE",SHE", "IT" "THEY", "THEM"))(ANIMATE))
<b>ACTION/STATE:</b>	((INTERPRET ("I" = "YOU" ("YOU" = "I") ("HE", "SHE", "IT" = ?) ("THEY", "THEM" = ?)))
<b>SUBSIDIARY FUNCTIONS:</b>	NIL

<b>CASE-NAME:</b>	CO-AGENT
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	((SELF = (PRO PERSON "I")) (OTHER = (PRO PERSON "YOU", "HE", "SHE", "IT" "THEY", "THEM")) (ANIMATE))
<b>ACTION/STATE:</b>	((INTERPRET ("I" = "YOU") ("YOU" = "I") ("HE", "SHE", "IT" = ?) ("THEY", "THEM" = ?)))
<b>SUBSIDIARY FUNCTIONS:</b>	NIL
<b>CASE-NAME:</b>	BENEFICIARY
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	((SELF = (PRO PERSON "I")) (OTHER = (PRO PERSON "YOU", "HE", "SHE", "IT" "THEY", "THEM")) (ANIMATE))
<b>ACTION/STATE:</b>	((INTERPRET ("I" = "YOU") ("YOU" = "I") ("HE", "SHE", "IT" = ?) ("THEY", "THEM" = ?)))
<b>SUBSIDIARY FUNCTIONS:</b>	NIL
<b>CASE-NAME:</b>	THEME
<b>IDENTITY-FILLERS:</b>	BOOKXYZ
<b>RESTRICTIONS:</b>	SUBGOAL-ELEMENT
<b>ACTION/STATE:</b>	NIL
<b>SUBSIDIARY FUNCTIONS:</b>	NIL
<b>CASE-NAME:</b>	CO-THEME
<b>IDENTITY-FILLERS:</b>	INDEF/SING
<b>RESTRICTIONS:</b>	BELIEF-ELEMENT
<b>ACTION/STATE:</b>	NIL
<b>SUBSIDIARY FUNCTIONS:</b>	NIL
<b>CASE-NAME:</b>	TO-LOCATION
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	ANIMATE
<b>ACTION/STATE:</b>	TO-CUSTOMER
<b>SUBSIDIARY FUNCTIONS:</b>	NIL
<b>CASE-NAME:</b>	FROM-LOCATION
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	ANIMATE,
<b>ACTION/STATE:</b>	FROM-BOOKSELLER
<b>SUBSIDIARY FUNCTIONS:</b>	NIL
<b>CASE-NAME:</b>	AT-POSSESSION
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	ANIMATE
<b>ACTION/STATE:</b>	WITH-BOOKSELLER
<b>SUBSIDIARY FUNCTIONS:</b>	NIL

<b>CASE-NAME:</b>	<b>TO-POSSESSION</b>
<b>IDENTITY-FILLERS:</b>	<b>SELF OTHER</b>
<b>RESTRICTIONS:</b>	<b>ANIMATE</b>
<b>ACTION/STATE:</b>	<b>TO-SELF</b>
<b>SUBSIDIARY FUNCTIONS:</b>	<b>NIL</b>

<b>CASE-NAME:</b>	<b>FROM-POSSESSION</b>
<b>IDENTITY-FILLERS:</b>	<b>SELF, OTHER</b>
<b>RESTRICTIONS:</b>	<b>ANIMATE</b>
<b>ACTION/STATE:</b>	<b>FROM-BOOKSELLER</b>
<b>SUBSIDIARY FUNCTIONS:</b>	<b>NIL</b>

What needs to be noted is that some of these CONTEXTFRAMEs would have been created prior to C's planning of her utterance and at the time of her interpretation of B's offer of help. This is because both UTTERANCEPLAN and INTERPRET use COMPILECONTEXT for processing information about the context. This is discussed below in the context of C's INTERPRET operation (5.2.9).

Having made a major decision as to what type of utterance is being formed UTTERANCEPLAN uses another operation to compile the remaining logical form of the utterance. This operation is CONSTRUCTLF. CONSTRUCTLF can inherit information from the GBSs as well as sub-goals and plan-methods already processed and activated. It also obtains information from the CONTEXTFRAMEs which contain information about the context in which the dialogue is taking place.

### **5.2.7 The bookseller's execution of CONSTRUCTLF**

The LOGFORM in which the logical form of the utterance is to be constructed is set up by UTTERANCEPLAN as has been previously noted. This operation starts the construction of the logical form by signifying the type of utterance it is to be and which in this instance is a Y/N QUERY. The next slot in the LOGFORM indicates the tense of the utterance being formed. This information derives from the context and generally defaults to PRES (present tense) unless otherwise indicated in the content of the sub-goal.

The dialogue is taking place in the present but reference could be made by either agent to future or past actions. These are signified by the constructs FUT (future tense)

and PAST (past tense) respectively. This information can derive either from the elements of an agent's sub-goal or from the context. Unless another tense is indicated from the propositions in the SBS it is assumed to be the PRES tense in which the utterance is being uttered. That is, unless another tense is indicated in the sub-goal of the agent, CONSTRUCTLF will place a PRES flag in the LOGFORM construction.

CONSTRUCTLF processes the current sub-goal and examines each element in turn before constructing the rest of the logical form. CONSTRUCTLF needs to make decisions as to how the elements in a sub-goal relate to each other. Some of the elements in the sub-goal will refer to objects but some of these objects can act as predicates in other contexts. What item becomes the main action in the logical form depends on the relationships between predicates and objects in the sub-goal. CONSTRUCTLF is assisted in this operation by being able to inherit information from the plan-methods and their slot fillers as well as the CONTEXTFRAMEs that have previously been activated or created.

The sub-goal belonging to B currently being processed is (WANTS, CUSTOMER, HELP) and is governed by the ~KNOW predicate. That is, B does not know whether C is in need of help. UTTERANCEPLAN has decided on a plan for the utterance and has commenced a LOGFORM with the beginning of this plan. This is;

(Y/N QUERY ( ....

In the absence of any contrary information contained in the sub-goal, CONSTRUCTLF identifies that the utterance to be made by B relates to the present context and therefore places the flag PRES in the LOGFORM as being the next construct. We then have;

(Y/N QUERY (PRES (....



In its examination of the elements in the proposition being processed, CONSTRUCTLF identifies one element to possess two senses, one in which it can stand as a state and the other in which it can serve as an action. This is the element HELP which is something that can either be received by an agent or carried out by an agent. In B's sub-goal, HELP is functioning as a state, governed by the predicate WANT and the first object CUSTOMER. HELP is a plan-method which has been previously activated and its STATE option identified. That is, HELP is a state and something that B wishes to offer to C.

This is because one of the selective restrictions governing the definition of HELP is that of OFFER-ASSISTANCE. A restriction relating to the OFFER-ASSISTANCE plan-method is whether the offer is being volunteered or has been requested. In this instance it is being volunteered and therefore a requisite of the OFFER-ASSISTANCE plan-method is the use of a modal auxiliary, signifying possibility. CONSTRUCTLF selects this restriction and adds the flag MOD/AUXpossib., to the LOGFORM. A lexical form for this construct would employ the auxiliary verb "can". The logical form for B's first utterance thus far then is;

(Y/N QUERY (PRES (MOD/AUXpossib. "CAN" (....

CONSTRUCTLF attempts to fill the remaining slots of the LOGFORM inheriting information for this purpose from any previous processing that has already been carried out and from the CONTEXTFRAMES. The agent who is making the utterance is signified by SELF in the AGENT slot of B's CONTEXTFRAME for agent and this signals to CONSTRUCTLF that the AGENT slot in this instance should be filled by the personal pronoun "I". This selection is signified by the options available in the RESTRICTIONS slot of the AGENT CONTEXTFRAME and previously identified when it was created.

Therefore, the developing logical form becomes;

(Y/N QUERY (PRES (MOD/AUX<sub>possib.</sub> "CAN"

(AGENT (PRO PERSON "I"))

The other cases that are relevant to the processing of this sub-goal are those of THEME and BENEFICIARY. When CONSTRUCTLF commenced processing the current sub-goal, the THEME CONTEXTFRAME would have been filled with the HELP element of the sub-goal along with any information that had been identified in the initial examination of this concept. HELP in this instance would have the information attached to it (via the plan-method for HELP) that CUSTOMER is to be the recipient of this help as identified in the sub-goal.

CUSTOMER is identified by CONSTRUCTLF as being the CO-AGENT in this instance and the IDENTITY-FILLERS slot of this CONTEXTFRAME indicate that the co-agent must be OTHER. Furthermore, the RESTRICTIONS slot of the CO-AGENT CONTEXTFRAME indicate that the PER PRO "YOU" is to be used in any utterance plan. However, not only is there a CO-AGENT CONTEXTFRAME in this instance but also a BENEFICIARY CONTEXTFRAME and in this instance the fillers from this frame take precedence over the CO-AGENT CONTEXTFRAME.

CONSTRUCTLF completes the LOGFORM for this particular utterance by including the THEME of HELP and the BENEFICIARY which is PER PRO "YOU";

(Y/N QUERY (PRES (MOD/AUX<sub>possib.</sub> "CAN"

(AGENT (PRO PERSON "I"))

(THEME (SCRIPT HELP))

(BENEFICIARY

(PRO(PERSON "YOU"))))))

### 5.2.8 The customer's execution of CONSTRUCTLF

Initially, at the commencement of this piece of dialogue both agents are in a similar position. They both wish to make initial enquiries of the other. The current sub-goal of C is (HAVE, BOOKSELLER, BOOKXYZ) that is, a proposition comprising of a

predicate and two arguments which are object concepts. The relationship between these elements is whether the first object (BOOKSELLER) has (i.e. HAVE) the second object (i.e. BOOKXYZ). This relationship was identified in the relationship between the slot fillers of the FROM, TO, and ACTION slots of the HAVE plan-method when it was activated (5.2.5).

CONSTRUCTLF selects first the predicate which governs the arguments of the proposition. This is the predicate HAVE, and this indicates to CONSTRUCTLF that an action is required for the utterance in order to indicate this type of action. This is placed in the next slot of C's LOGFORM which is developing as follows;

(Y/N QUERY (PRES (HAVE (.....

CONSTRUCTLF then processes the remaining elements of the proposition inheriting information from the previously processed CONTEXTFRAMEs. The IDENTITY slot of the AGENT CONTEXTFRAME indicates that SELF in this instance is "I" because self is the agent making the utterance. The person to whom the utterance is being addressed is viewed as being the CO-AGENT in the interaction. Therefore, information is obtained from the CO-AGENT CONTEXTFRAME which indicates that in this instance, the CO-AGENT should be referred to as YOU. The logical form under construction then becomes;

(Y/N QUERY (PRES (HAVE (CO-AGENT (PRO PERSON "YOU") ... )

The last element in the proposition comprising the sub-goal is BOOKXYZ. This is the theme of what this proposition and sub-goal is concerned with. BOOKXYZ refers to a particular copy of a book and not to more than one. Although the bookseller might have a number of copies of BOOKXYZ available for sale, C is only concerned with buying one of the copies. CONSTRUCTLF takes this single element of the

proposition but displays it in the logical form as consisting of two elements of information.

The reason for this is that CONSTRUCTLF derives information from both the THEME CONTEXTFRAME as well as the CO-THEME CONTEXTFRAME. The reader will remember that when the CONTEXTFRAMEs were activated and filled in for this particular sub-goal, the THEME CONTEXTFRAME identified the THEME of this sub-goal as being BOOKXYZ and the CO-THEME was identified as being a single copy, that is, INDEF/SING (5.2.5).

The information concerning determiners is contained in the agents' GBSs and relates to their knowledge about the use of reference and how to express this in language. CONSTRUCTLF retrieves this information from the THEME and CO-THEME slots of the CONTEXTFRAME respectively, using their contents to complete the logical form of the utterance. When displayed to the other agent it must be in a form that makes clear that a single copy of the book is what is required, and places this in the LOGFORM. Thus we now have;

(Y/N QUERY (PRES (I HAVE (CO-AGENT (PRO PERSON "YOU")  
(THEME (BOOKXYZ)  
(CO-THEME (INDEF/SING COPY))))))

The process by which each agent forms utterances in accord with their beliefs and goals has been described. From this process we know what the bookseller's goals are and how this governs the type of utterance her opening move is going to be. We also know the type of utterance the customer is composing to further her goals. What hasn't been made explicit at this point is what happens following B's opening utterance. How is B's utterance interpreted by C and how does it affect her own utterance. The first cycle of this dialogue is not complete until the INTERPRET operation for C has been described.

### **5.2.9 The customer's operation of INTERPRET.**

B displays her utterance to C. Within the context of the model this is a logical form as indicated above. It is assumed that C's knowledge of language and the speech community in which she is situated is similar to that of B and therefore predisposes her to be able to access the content of B's utterance via its logical form. What C constructs in interpreting B's logical form, is assumed to correspond to B's logical form as realised in natural language. She expects certain aspects of this to be significant and familiar, especially the type of components used and its order. She employs her facility for constructing logical forms for interpreting the logical forms of others. The template that is used for piecing together her own logical forms is used to piece together the incoming information which will be interpreted according to her GBS and her CONTEXTFRAMES.

Initially, C's INTERPRET operation identifies the type of utterance made by the speaker as to whether it is a DECLARE, ASK or COMMAND type. If the utterance is a DECLARE type of utterance, the content of this is processed by C and any new information is added to her GBS. What type of response she makes or even whether she makes a response will depend on the content of this DECLARE in relation to her GBS and her own goals and purposes. A COMMAND type of utterance is processed in a similar manner but the response may be some physical action or behaviour. An ASK type of utterance indicates to C that a verbal response is required by the speaker.

The operation INTERPRET uses knowledge of plan-methods to process the incoming logical form. For example, there are different options for dealing with DECLARE, ASK and COMMAND type utterances and these are identified in the ACTION slots of the plan-method functions. When an ASK type of utterance is identified, INTERPRET invokes immediately a LOGFORM to prepare for a response but first completes the processing of the incoming logical form. The logical form for B's first utterance is:

(Y/N QUERY (PRES (MOD/AUXpossib. "CAN"

(AGENT (PRO PERSON "I"))

(THEME (SCRIPT HELP))

(BENEFICIARY

(PRO (PERSON "YOU"))))))

B's logical form is interpreted by C in the following manner. Initially, the LOGFORM is identified as commencing with a Y/N QUERY and therefore a Y/N QUERY plan-method is activated and the slots filled in.

**NAME:** Y/N QUERY  
**OBJECT:** HELP (STATE)  
**FROM:** BOOKSELLER  
**TO:** CUSTOMER  
**ACTION:** ((TO = ASK (KNOWIF-QUESTION))  
(FROM = (REPLY (DECLARE))))

The MOD/AUXpossib. is identified as being the lexical item "CAN" from the definition of this category in C's GBS. This signifies to C the possibility of an offer of assistance. The AGENT signified as PRO PERSON "I" is identified as being the CO-AGENT from C's perspective and therefore "I" is interpreted as referring to B. HELP is identified as being the THEME of the logical form and a HELP plan-method is activated. The slots of this are filled with the incoming information:

**NAME:** HELP  
**OBJECT:** NIL  
**FROM:** BOOKSELLER  
**TO:** CUSTOMER  
**ACTION:** ((FROM = OFFER-ASSISTANCE)  
(TO = ACCEPT-ASSISTANCE))

No object is identified in the logical form of the utterance so the OBJECT slot in this plan-method is left unfilled. The utterance has been made by B so the FROM slot is filled with this agent, that is the BOOKSELLER. The TO slot defaults to SELF or CUSTOMER, that is, the agent receiving the incoming information. Finally, INTERPRET identifies from the ACTION slot that the relationship between FROM

and TO indicates that the filler of the FROM slot is making the offer of assistance and the occupier of the TO slot should accept this offer. The PRO PERSON "YOU" is interpreted by C as referring to herself.

As well as the Y/N QUERY and HELP plan-methods being activated at this point to aid in C's interpretation of B's utterance, CONTEXTFRAMES are also created. The reader will remember from 5.2.5 that a number of CONTEXTFRAMES were created when C formulated a plan for her utterance. However, it has also been previously noted that in this scenario, C does not form her reply until after B has made her offer of help and therefore the activation of the CONTEXTFRAMES previously described, would not have been activated until C's first operation of INTERPRET.

What needs to be emphasized is that both UTTERANCEPLAN and INTERPRET use COMPILECONTEXT to create CONTEXTFRAMES in order to obtain essential information about the situation in which the dialogue is taking place. INTERPRET's use of COMPILECONTEXT at this point in the process creates the following CONTEXTFRAMES:

<b>CASE-NAME:</b>	AGENT
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	((SELF = (PRO PERSON "I")) (OTHER = (PRO PERSON "YOU", "HE", "SHE", "IT" "THEY", "THEM") (ANIMATE)))
<b>ACTION/STATE:</b>	((INTERPRET ("I" = "YOU") ("YOU" = "I") ("HE", "SHE", "IT" = ?) ("THEY", "THEM" = ?)))
<b>SUBSIDIARY FUNCTIONS:</b>	NIL
 <b>CASE-NAME:</b>	 CO-AGENT
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	((SELF = (PRO PERSON "I")) (OTHER = (PRO PERSON "YOU", "HE", "SHE", "IT" "THEY", "THEM") (ANIMATE)))
<b>ACTION/STATE:</b>	((INTERPRET ("I" = "YOU") ("YOU" = "I") ("HE", "SHE", "IT" = ?) ("THEY", "THEM" = ?)))
<b>SUBSIDIARY FUNCTIONS:</b>	NIL

**CASE-NAME:** BENEFICIARY  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ((SELF = (PRO PERSON "I")) (OTHER  
= (PRO PERSON "YOU", "HE",  
"SHE", "IT" "THEY", "THEM")  
(ANIMATE))  
**ACTION/STATE:** ((INTERPRET ("I" = "YOU")  
("YOU" = "I")  
("HE", "SHE", "IT" = ?)  
("THEY", "THEM" = ?)))  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** THEME  
**IDENTITY-FILLERS:** HELP  
**RESTRICTIONS:** SUBGOAL-ELEMENT  
**ACTION/STATE:** NIL  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** TO-LOCATION  
**IDENTITY-FILLERS:** SELF OTHER  
**RESTRICTIONS:** ANIMATE  
**ACTION/STATE:** TO-CUSTOMER  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** FROM-LOCATION  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ANIMATE,  
**ACTION/STATE:** FROM-BOOKSELLER  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** AT-POSSESSION  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ANIMATE  
**ACTION/STATE:** WITH-BOOKSELLER  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** TO-POSSESSION  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ANIMATE  
**ACTION/STATE:** TO-YOU  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** FROM-POSSESSION  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ANIMATE  
**ACTION/STATE:** FROM-SELF  
**SUBSIDIARY FUNCTIONS:** NIL

As these CONTEXTFRAMEs are created the slots are filled with the relevant options indicating the contextual circumstances from C's perspective. B's use of the PER PRO "I" is interpreted by C's INTERPRET operation as being an AGENT



CONTEXTFRAME in this instance and the PER PRO "YOU" as being a CO-AGENT CONTEXTFRAME. This is because each agent views the one who is making the utterance as being the AGENT and the receiving party as the CO-AGENT. Furthermore, C views herself as being the BENEFICIARY in this instance which information is defined by the HELP plan-method previously activated and which indicated that she was to receive the HELP whilst B was to give the HELP.

Accordingly, the appropriate slots of the other relevant CONTEXTFRAMEs, i.e. THEME, TO-LOCATION, FROM-LOCATION, AT-POSSESSION, and FROM-POSSESSION are filled.

The elements contained in B's logical form compose a proposition (HELP, BOOKSELLER, CUSTOMER) which is interpreted as such by C's INTERPRET operation. This proposition is new information for C and now becomes part of her GBS. It has been noted that a restriction on the HELP plan-method is that of ACCEPT-ASSISTANCE, another plan-method. This is processed by INTERPRET in this instance given the restrictions governing the FROM and TO slots of the HELP plan-method.

<b>NAME:</b>	HELP
<b>OBJECT:</b>	NIL
<b>FROM:</b>	BOOKSELLER
<b>TO:</b>	CUSTOMER
<b>ACTION:</b>	((FROM = OFFER-ASSISTANCE) (TO = ACCEPT-ASSISTANCE))

ACCEPT-ASSISTANCE is another plan-method which contains information as to how an ACCEPT can be made and has attached to it an action which is an affirmative response and could be signalled to B by C making a formulaic type of utterance such as the form "YES PLEASE".

<b>NAME:</b>	ACCEPT-ASSISTANCE
<b>OBJECT:</b>	HELP
<b>FROM:</b>	BOOKSELLER
<b>TO:</b>	CUSTOMER
<b>ACTION:</b>	(ASSERT-AFFIRMATIVE (FORMULAIC "YES PLEASE"))

INTERPRET has completed its task but the ACCEPT-ASSISTANCE plan-method indicates that a response needs to be made. Furthermore, the ACTION slot of the Y/N QUERY plan-method used by INTERPRET to process B's LOGFORM also indicates that a REPLY should be made to this type of response. Where two or more plan-methods might have been activated by INTERPRET in the interpretation of a logical form, as in this instance, the last one to be activated is selected to provide the next action for the continuing process. There is an amount of redundancy in the process and if the last plan-method to be activated is unable to provide any further action one of the previously activated plan-methods can be selected for this purpose.

The type of action and response required having been selected, control returns to UTTERANCEPLAN. UTTERANCEPLAN makes an analysis of the ACCEPT-ASSISTANCE element options as it does initially with a sub-goal.

UTTERANCEPLAN begins the construction of the LOGFORM and fills the first slot with a DECLARE type utterance such as ASSERT. This type of utterance plan has been indicated by the ACTION slot of the ACCEPT-ASSISTANCE plan-method. It also uses a COMPILECONTEXT operation to create any further CONTEXTFRAMEs that are needed for the planned utterance. In this instance a THEME CONTEXTFRAME is required and COMPILECONTEXT creates one;

<b>CASE-NAME:</b>	<b>THEME</b>
<b>IDENTITY-FILLERS:</b>	<b>AFFIRMATIVE</b>
<b>RESTRICTIONS:</b>	<b>SCRIPT-ELEMENT</b>
<b>ACTION/STATE:</b>	<b>NIL</b>
<b>SUBSIDIARY FUNCTIONS:</b>	<b>NIL</b>

The tense of B's logical form that has been interpreted by C is present tense. There is no information that anything with respect to tense has changed and UTTERANCEPLAN identifies that a response is required in the same tense. The tense slot of the LOGFORM is filled with a PRES tense flag. CONSTRUCTLF begins to compile the logical-form for the utterance;

(ASSERT (PRES (...

CONSTRUCTLF obtains from the THEME slot of the CONTEXTFRAME the theme of affirmation to B's offer of help and inserts this into the LOGFORM under construction. Thus;

(ASSERT (PRES (THEME AFFIRMATIVE(formulaic "YES PLEASE"))))

No other case frame information is conveyed in this logical form as it is not required by B for an understanding of C's response. This is because B's INTERPRET operation will process the response, in a similar manner as described above, and identifies from the HELP and OFFER-ASSISTANCE plan-methods (previously activated when B made her offer of help) that C's AFFIRMATIVE is an ACCEPT response to her OFFER-ASSISTANCE. B asked a question of a yes/no type and an affirmation response is all that is required in reply.

At this stage in the process, C having made a response to B's offer of assistance decides to make another utterance in furtherance of her goals and to explain to B the type of assistance that is required. The model does not capture this process explicitly. Much of the reasoning behind these two moves lies in the knowledge both participants have about making offers of help and their acceptance. This is knowledge both agents know about the pragmatics of language which is likely to be extensive. It is not my intention to represent this type of knowledge in the model apart from that which the plan-methods capture in a small way.

It is likely that B, having made an offer of assistance not only waits for a positive response but in the event of receiving a positive response is also prepared for a following utterance indicating what sort of help is required. Therefore, at this stage of the dialogue C makes her second utterance to achieve her goals (described above at 5.2.5) which is then interpreted by B. First though, B's INTERPRET operation of both C's utterances will be described. They are:

(ASSERT (PRES (THEME AFFIRMATIVE(formulaic "YES PLEASE"))))

(Y/N QUERY (PRES (HAVE (CO-AGENT (PRO PERSON "YOU")  
(THEME (BOOKXYZ)  
(CO-THEME (INDEF/SING COPY))))))

#### 5.2.10 The bookseller's operation of INTERPRET

Following a similar operation of interpretation to that described above, B interprets the response of C. INTERPRET identifies the first move in C's response as being an ASSERT type of utterance which indicates to B that C is following a DECLARE type of plan for her utterance. It must be remembered that within the model, this ASSERT information is carried in the logical form. It is assumed that this element would correspond to certain linguistic objects and cues in natural language. INTERPRET obtains this information from activating the ASSERT plan-method and identifying that an AFFIRMATIVE response is a DECLARE type of plan and which matches the AFFIRMATIVE in C's logical form:

NAME: ASSERT  
OBJECT: NIL  
FROM: CUSTOMER  
TO: BOOKSELLER  
ACTION: (DECLARE (INFORMIF = (AFFIRMATIVE = YES,  
NEGATIVE = NO)) (INFORMINFO = OTHER))

The AFFIRMATIVE element activates the ACTION slot of the ACCEPT-ASSISTANCE plan-method and so indicates to B that her offer of assistance has been accepted by C.

NAME: ACCEPT-ASSISTANCE  
OBJECT: HELP  
FROM: BOOKSELLER  
TO: CUSTOMER  
ACTION: (ASSERT-AFFIRMATIVE (FORMULAIC "YES PLEASE"))

B's knowledge of the ACCEPT-ASSISTANCE plan-method and its relationship and linkage to the OFFER-ASSISTANCE and HELP plan-methods indicates to B that

this sub-goal has been achieved and that the customer has signified that she does want help. Therefore, the sub-goal (WANTS, CUSTOMER, HELP) is removed from the goal tree and placed in her GBS where it becomes a belief that is known that the customer wants help. B's goal-tree is now in the state signified in Figure 5.3 (1).

Furthermore, B's belief set is in the following state<sup>1</sup>.

(SELL, BOOKSELLER, BOOK) & (WANT, BOOKSELLER, a, b)  
& ((BUY, CUSTOMER, BOOKS) = a) & ((HIGHVAL, BOOKS) = b)

(~KNOW, BOOKSELLER) & (IF a, b, c, d)  
    & ((KNOW, CUSTOMER) = a )  
    & (PAPEROVERS, BOOKXYZ) = b )  
    & ( HARDCOVER, BOOKXYZ) = c )  
    & (VALUE, BOOKXYZ) = d))

(KNOW, BOOKSELLER, a ) & ((WANTS, CUSTOMER, HELP) = a)  
(BOOKSELLER, I)  
(CUSTOMER, YOU)  
(BOOKSELLER, SELF)

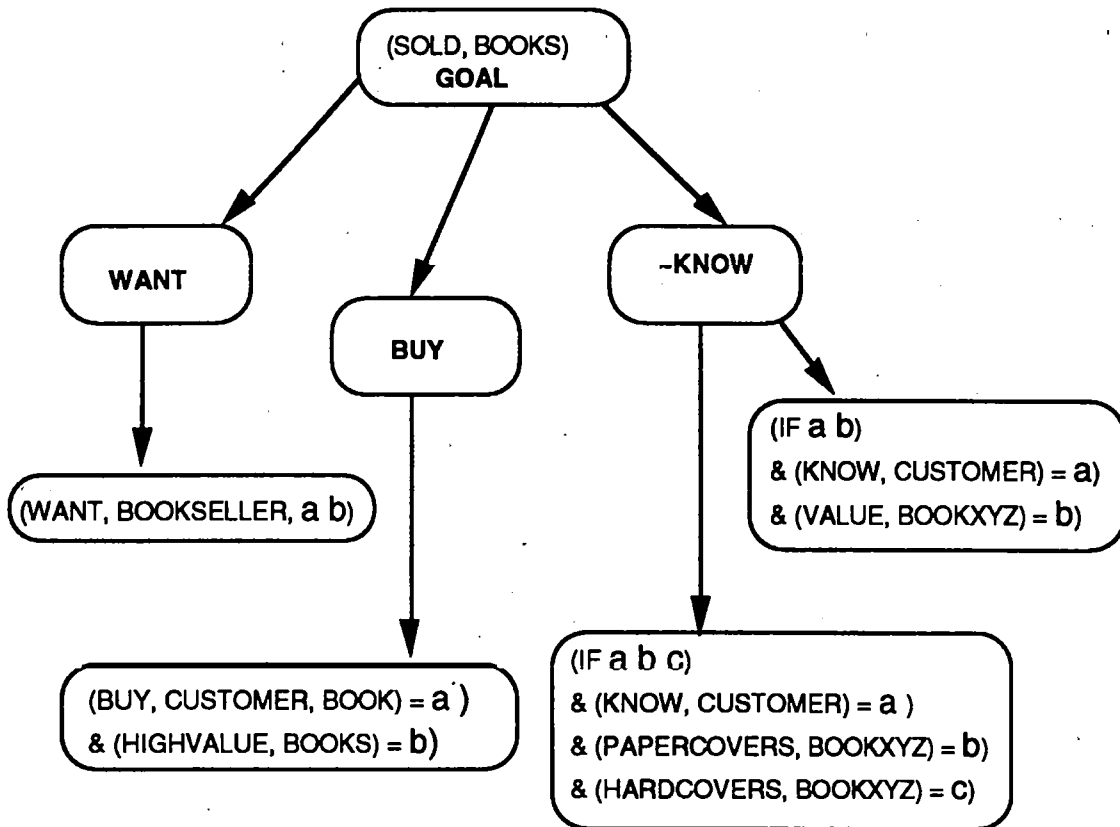
C makes another move and B's INTERPRET operation remains activated. INTERPRET then processes the second utterance of C;

(Y/N QUERY (PRES (HAVE (CO-AGENT (PRO PERSON "YOU")  
                                    (THEME (BOOKXYZ)  
                                    (CO-THEME (INDEF/SING COPY))))))

The Y/N QUERY element of C's logical form signals to B's INTERPRET operation that an ASK type plan is being used. This information is obtained from the ACTION slot of the Y/N QUERY plan-method which has been activated;

---

<sup>1</sup> The general beliefs that pertain to both agents are not reproduced in these tables but can be found in the complete list of both agent's beliefs in Appendix 1



**Figure 5.3 The revised Bookseller's  
Goal-tree (1)**

**NAME:** Y/N QUERY  
**OBJECT:** NIL  
**FROM:** BOOKSELLER  
**TO:** CUSTOMER  
**ACTION:** ((TO = ASK (KNOWIF-QUESTION))  
 (FROM = (REPLY (DECLARE, ASK, COMMAND))))

An option in the ACTION slot of this plan-method indicates that C's utterance is of the KNOWIF category in an ASK plan and that it requires a response from B. The element HAVE indicates to B that the main action of this utterance concerns the state POSSESS and this information is derived from activation of the HAVE plan-method;

**NAME:** HAVE  
**OBJECT:** BOOKXYZ  
**FROM:** BOOKSELLER  
**TO:** CUSTOMER  
**ACTION:** (POSSESS (STATE))

B's CONTEXTFRAMEs are also used to interpret C's utterance and are also activated;

**CASE-NAME:** AGENT  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ((SELF = (PRO PERSON "I")) (OTHER = (PRO PERSON "YOU", "HE", "SHE", "IT" "THEY", "THEM") (ANIMATE)))  
**ACTION/STATE:** ((INTERPRET ("I" = "YOU") ("YOU" = "I") ("HE", "SHE", "IT" = ?) ("THEY", "THEM" = ?)))  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** CO-AGENT  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ((SELF = (PRO PERSON "I")) (OTHER = (PRO PERSON "YOU", "HE", "SHE", "IT" "THEY", "THEM") (ANIMATE)))  
**ACTION/STATE:** ((INTERPRET ("I" = "YOU") ("YOU" = "I") ("HE", "SHE", "IT" = ?) ("THEY", "THEM" = ?)))  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** THEME  
**IDENTITY-FILLERS:** BOOKXYZ  
**RESTRICTIONS:** SUBGOAL-ELEMENT  
**ACTION/STATE:** NIL  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** CO-THEME  
**IDENTITY-FILLERS:** INDEF/SING  
**RESTRICTIONS:** BELIEF-ELEMENT  
**ACTION/STATE:** NIL  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** TO-LOCATION  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ANIMATE  
**ACTION/STATE:** TO-CUSTOMER  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** FROM-LOCATION  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ANIMATE,  
**ACTION/STATE:** FROM-BOOKSELLER  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** AT-POSSESSION  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ANIMATE  
**ACTION/STATE:** WITH-BOOKSELLER  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** TO-POSSESSION  
**IDENTITY-FILLERS:** SELF OTHER  
**RESTRICTIONS:** ANIMATE  
**ACTION/STATE:** TO-SELF  
**SUBSIDIARY FUNCTIONS:** NIL

**CASE-NAME:** FROM-POSSESSION  
**IDENTITY-FILLERS:** SELF, OTHER  
**RESTRICTIONS:** ANIMATE  
**ACTION/STATE:** FROM-BOOKSELLER  
**SUBSIDIARY FUNCTIONS:** NIL

B's INTERPRET operation identifies the AGENT (PRO PERSON "YOU") as relating to the POSSESS element of the HAVE plan-method and therefore identifies it as relating to herself. The ACTION slot of the AGENT CONTEXTFRAME indicates that an agent receiving a PER PRO "YOU" is to interpret this as "I", that is, SELF. Furthermore, INTERPRET identifies from the other relevant CONTEXTFRAMEs the THEME as being a particular object, namely BOOKXYZ, and the CO-THEME as identifying this object as being a single definite copy. Other CONTEXTFRAMEs contain the information as to where this object is in terms of location and possession.

A complete cycle of the dialogue has now been completed and is:

B. (Y/N QUERY (PRES (MOD/AUX<sub>possib.</sub> "CAN"  
 (AGENT (PRO PERSON "I"))  
 (THEME ( HELP))  
 (BENEFICIARY  
 (PRO (PERSON "YOU"))))))

C. (ASSERT (PRES (THEME AFFIRMATIVE  
 (formulaic "YES PLEASE")))

(Y/N QUERY (PRES (HAVE (AGENT (PRO PERSON "YOU")  
 (THEME (BOOKXYZ))  
 (CO-THEME (INDEF/SING "COPY")))))



### 5.2.11 The second cycle of dialogue

The major operations governing the processing of the model have now been described. For the remaining cycles of the dialogue only the names of these operations will be used. This offers a more succinct view of how the logical forms of each agent are derived from their sub-goals and how these are achieved and the GBSs of each agent are updated. The next cycle of dialogue to be processed is:

4.     B     Yes, I have them, both in papercovers and hardcovers.
5.     C     How much is the papercover copy?

The next sub-goal of B's awaiting processing is:

(IF a, b, c, )  
& ((KNOW, CUSTOMER) = a)  
& (PAPERCOVERS, BOOKXYZ) = b)  
& (HARDCOVERS, BOOKXYZ) = c)

This is attached to the ~KNOW predicate node and so indicates that B doesn't know whether the customer knows that the book she wants is available in papercovers or hardcovers. Another sub-goal relates to the value of the book and again is an element B doesn't know whether C has knowledge of. This information relates to B's earlier sub-goals of wanting the customer to buy books of a high value. B has the knowledge that hardcover books are generally more expensive than papercovers and that this means more profit for her. Her intention therefore, is to make the information available to C that both types of book cover for this title are available.

To realize this sub-goal, B formulates a DECLARE plan for displaying this information. The LOGFORM therefore begins with an ASSERT type of utterance. The utterance to be made is to be in the present tense and so the flag PRES fills the tense slot of the LOGFORM. Next, the AGENT slot is filled with PRO PERSON "I" indicating that B is the agent of this utterance. The main action slot contains the

element HAVE indicating that B has the following items in her POSSESSiON. The THEME for this utterance relates to two items she has and wants to display to C. It utilizes the determiner 'both', that is, DET "BOTH" the meaning and use of which is defined in her GBS. The CO-THEME relates to the cover types available, paper and hardcovers. Thus, the logical form for B's next utterance which is displayed to C is:

(ASSERT (PRES (HAVE (AGENT (PRO PERSON "I"))  
 (THEME (DET "BOTH"))  
 (CO-THEME (PAPERCOVERS & HARDCOVERS))))))

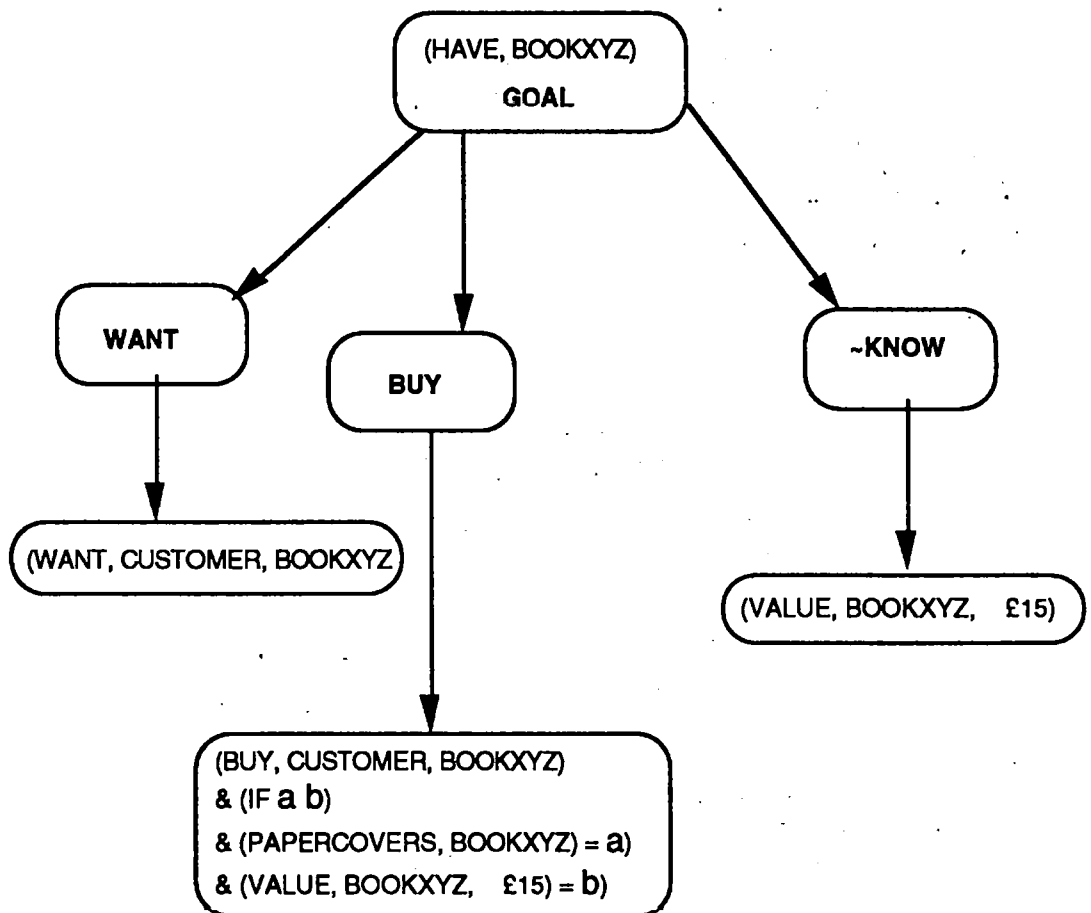
C interprets this logical form in the manner previously described and identifies that two of her sub-goals have been achieved. One of her sub-goals was (HAVE, BOOKSELLER, BOOKXYZ) and B's reply indicates that she does have this book available for sale. This knowledge that she did not know, becomes known to her, following the display of B's logical form, so this sub-goal is removed from her goal-tree and placed in her GBS becoming a proposition that is known.

Another sub-goal was (PAPERCOVERS, BOOKXYZ), that is, C did not know whether the specific book title she was wanting to buy had papercovers. In the logical form displayed by B this sub-goal was also met, in that the information was provided for her without C having to ask for it specifically. Accordingly, she does not have to ask for something she already knows and this sub-goal is also removed from the tree and is placed in her GBS as knowledge which is now known. C's goal-tree is now in the state as shown in Figure 5.4 (1) overleaf and her belief set is now in the following state:

(HAVE, CUSTOMER, BOOKXYZ) & (WANT, CUSTOMER, BOOKXYZ )  
 & (IF a, b, c (BUY, CUSTOMER, BOOKXYZ)  
 & ((HAVE, BOOKSELLER, BOOKXYZ) = a)  
 & ((PAPERBACK, BOOKXYZ) = b)  
 & ((VALUE£15, BOOKXYZ) = c )

(~KNOW, CUSTOMER) & (IF c)  
 & ((VALUE£15, BOOKXYZ) = c)

(PAPERCOVERS, BOOKXYZ)  
 (HARDCOVERS, BOOKXYZ)  
 (HAVE, BOOKSELLER, BOOKXYZ)  
 (CUSTOMER, SELF)  
 (CUSTOMER, I)  
 (BOOKSELLER, YOU)



**Figure 5.4 The revised Customer's  
 Goal-tree (1)**

B's goal-tree at this stage is now in the state signified by Figure 5.5 (2) below and her belief-set at this stage is now the following;

(SELL, BOOKSELLER, BOOK) & (WANT, BOOKSELLER, a, b)  
 & ((BUY, CUSTOMER, BOOKS) = a) & ((HIGHVAL, BOOKS) = b)

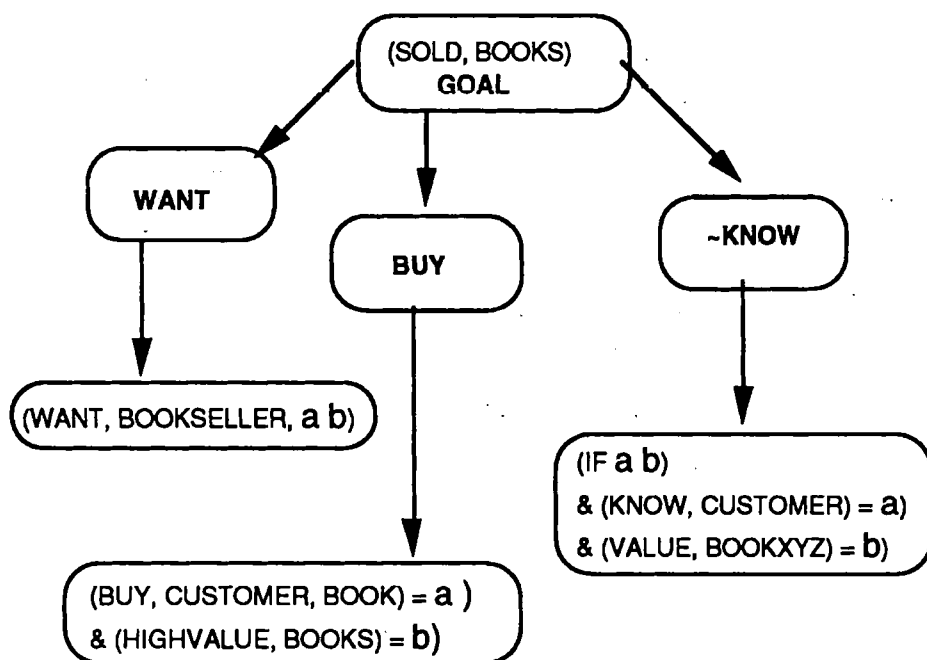
(~KNOW, BOOKSELLER) & (IF a,)  
 & (VALUE£15, BOOKXYZ) = a))

((KNOW, BOOKSELLER, a) & ((WANTS, CUSTOMER, HELP) = a))  
 ((KNOW, CUSTOMER) = a, b, )  
 & (PAPERCOVERS, BOOKXYZ) = a)  
 &( HARDCOVER, BOOKXYZ) = b )

(BOOKSELLER, SELF)

(BOOKSELLER, I).

(CUSTOMER, YOU)



**Figure 5.5 The revised Bookseller's  
Goal-tree (2)**

Once B has DECLARED the information to C that the BOOKXYZ she would like to buy is available in PAPERCOVERS and HARDCOVERS the sub-goal is removed from her goal-tree and the propositions composing the beliefs of this sub-goal, as well as the additional information furnished by B becomes part of her GBS and which now indicates that C possesses this information.

The remaining piece of knowledge C requires to achieve her goal is to know the price of the book. Accordingly she plans an utterance which will achieve this sub-goal. She requires information in this instance and therefore, employs an ASK plan for the formation of her LOGFORM. The information she requires is not simply of the yes or no type and so a KNOWINFO category of ASK plan is required. The LOGFORM for this utterance will start with a WH-QUERY signifying that information is being sought. The present tense is being used and so the PRES flag appears next in the LOGFORM.

The main action of the utterance relates to a quantity element, that is, the value of the book in paperback. The lexical form for this quantity type of concept is realized by the use of the adverb "how" and is one of the lexical forms which signify to a hearer that a WH-QUERY is being made. The lexical form "how" is the only WH word which is not spelt with a WH and is defined as a plan-method in the model.

<b>NAME:</b>	WH- QUERY
<b>OBJECT:</b>	NIL
<b>FROM:</b>	CUSTOMER
<b>TO:</b>	BOOKSELLER
<b>ACTION:</b>	((TO = ASK (KNOWINFO-QUESTION)) (FROM = (REPLY (DECLARE, ASK, COMMAND)))

The particular query being made concerns the value of the papercover copy of the book, that is, how much does it cost? This is the THEME of this utterance and its CO-THEME is the element PAPERCOVERS.

<b>CASE-NAME:</b>	THEME
<b>IDENTITY-FILLERS:</b>	VALUE
<b>RESTRICTIONS:</b>	SUBGOAL-ELEMENT
<b>ACTION/STATE:</b>	NIL
<b>SUBSIDIARY FUNCTIONS:</b>	NIL

<b>CASE-NAME:</b>	CO-THEME
<b>IDENTITY-FILLERS:</b>	PAPERCOVERS
<b>RESTRICTIONS:</b>	BELIEF-ELEMENT
<b>ACTION/STATE:</b>	NIL
<b>SUBSIDIARY FUNCTIONS:</b>	NIL

Therefore the complete logical form for C's next utterance is:

```
(WH-QUERY (PRES ("HOW" (THEME ( VALUE))
                    (CO-THEME (PAPERCOVERS))))))
```

This logical form is interpreted by an INTERPRET operation of B. The type of utterance is identified from the WH-QUERY plan-method as being an ASK plan of the KNOWINFO kind. The request for information relates to the value of the paperback copy of the BOOKXYZ. B identifies that the element relating to PAPERCOVERS in this logical form refers to BOOKXYZ of C's earlier utterance. B obtains this information from the record of the earlier logical forms in the conversation.

The record of this earlier conversation would have marked the elements PAPERCOVERS and HARDCOVERS in B's second utterance as referring to BOOKXYZ in the second part of C's first utterance. B knows both the value of the PAPERCOVERS and HARDCOVERS as this knowledge is contained in her GBS. Consequently, B plans an utterance to DECLARE this information to C.

#### 5.2.12 The last cycle of dialogue

6. B. £15.
7. C. I'll take it.

As previously noted the WH-QUERY contained in C's logical form signals to B that information is required by the speaker which information is derived from the ACTION slot of this plan-method and that she needs to make a reply.

Two elements contained in C's query relate to two elements in the remaining sub-goal of B. C's query to B about not knowing the price of BOOKXYZ is confirmation of B's belief. A LOGFORM is invoked by B's UTTERANCEPLAN to contain the logical form for a reply which is then constructed by CONSTRUCTLF. The plan for the utterance is of the DECLARE type and so the flag ASSERT is chosen to fill the first slot of the LOGFORM and indicates what type of utterance it is. The utterance is of the present tense so the tense flag PRES fills the second slot. The THEME and CO-THEME are the value of the book and the papercovers edition, respectively. In natural language the third person singular pronoun could be used by B to refer C's attention to the object of the utterance and which has previously been referred to. This could be realized by the lexical form of 'it'.

The action in this utterance concerns something being something else. The reader will remember that the copula has been omitted in the propositional forms being used (4.3.1) but that the second element in the proposition is governed by the first. Thus in this instance £15 is governed by VALUE, that is, the value is £15. The logical form for this utterance then is;

(ASSERT (PRES (THEME (VALUE £15 ))  
(CO-THEME PAPERCOVERS))))

Once this utterance has been made by B the sub-goal is removed from the goal-tree and the proposition (KNOW, CUSTOMER, VALUE£15) is placed in B's GBS. B's goal-tree is now in the state as in Figure 5.6 (3) overleaf and her belief set is:

(SELL, BOOKSELLER, BOOK) & (WANT, BOOKSELLER, a, b)  
 & ((BUY, CUSTOMER, BOOKS) = a) & ((HIGHVAL, BOOKS) = b)

((KNOW, BOOKSELLER, a ) & ((WANTS, CUSTOMER, HELP) = a))  
 ((KNOW, CUSTOMER) = a, b, c)

& ((PAPERCOVERS, BOOKXYZ) = a)

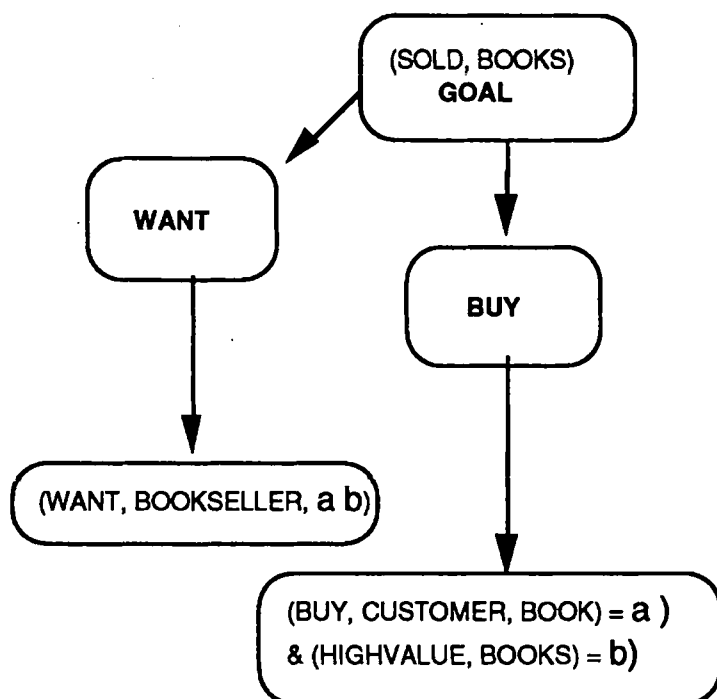
& ((HARDCOVER, BOOKXYZ) = b )

& ((VALUE£15, BOOKXYZ) = c))

(BOOKSELLER, SELF)

(BOOKSELLER, I)

(CUSTOMER, YOU)



**Figure 5.6 The revised Bookseller's  
Goal-tree (3)**

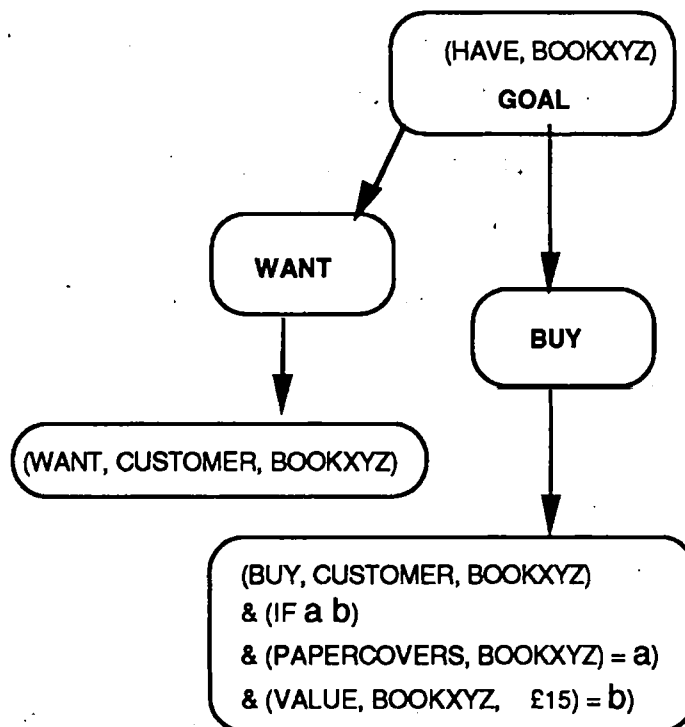
From the display of B's logical form, C makes an INTERPRET operation and learns that the THEME of this utterance relates to a VALUE and that this in turn relates to the CO-THEME which is the PAPERBACK edition of the book. The filler of the THEME slot, VALUE£15 is an item of fresh information but which also relates to an item in her remaining sub-goal, that is, (VALUE£15, BOOKXYZ). This sub-goal is attached to the ~KNOW predicate node which motivated her forming an utterance to



obtain the information. This information is now known to her and therefore the sub-goal is removed from the tree and the proposition (VALUE£15, BOOKXYZ) is placed in her GBS. The current states of C's goal-tree and GBS are now in the state as shown below in Figure 5.7 (2).

The sub-goals emanating from the ~KNOW predicate node in C's goal-tree have now been achieved. The recursive process of ACHIEVEGOAL now begins to unwind and ACHIEVEGOAL removes the ~KNOW predicate node as it has been completed and has no further use.

ACHIEVEGOAL unwinds to the next predicate node which is BUY. C now has all the information necessary to accomplish her action of BUY and so



**Figure 5.7 The revised Customer's  
Goal-tree (2)**

C's belief-set is now the following:

(HAVE, CUSTOMER, BOOKXYZ) & (WANT, CUSTOMER, BOOKXYZ)  
& (IF a, b, c (BUY, CUSTOMER, BOOKXYZ)  
& ((HAVE, BOOKSELLER, BOOKXYZ) = a)

& ((PAPERBACK, BOOKXYZ) = b)

& ((VALUE£15, BOOKXYZ) = c )

(VALUE, £15, BOOKXYZ)

(PAPERCOVERS, BOOKXYZ)

(HARDCOVERS, BOOKXYZ)

(HAVE, BOOKSELLER, BOOKXYZ)

(CUSTOMER, SELF)

(CUSTOMER, I)

(BOOKSELLER, YOU)

the NOTYET flag is removed from the action slot of this plan-method, which was previously activated but held over for later processing, and the BUY sub-goal is put into action, that is, (BUY, CUSTOMER, BOOKXYZ). The other elements attached to this sub-goal have now been satisfied. That is, C contains in her GBS the knowledge that the BOOKXYZ is available in papercovers and is of a value equivalent to £15. These conditions having been satisfied the BUY sub-goal can proceed. ACHIEVEGOAL activates the BUY plan-method and an EXCHANGE-MONEY operation is identified.

<b>NAME:</b>	BUY
<b>OBJECT:</b>	BOOKXYZ
<b>FROM:</b>	BOOKSELLER
<b>TO:</b>	CUSTOMER
<b>ACTION:</b>	EXCHANGE (MONEY FOR OBJECT)

The plan-method EXCHANGE is used by C to complete the purchase of the book and an action associated with carrying out this plan-method indicates that an utterance needs to be made to signify the purchase. That is, that the exchange needs to be affirmed by an ASSERT type of utterance. UTTERANCEPLAN uses this action to elicit a LOGFORM and CONSTRUCTLF constructs C's last utterance in this dialogue.

**NAME:** EXCHANGE  
**OBJECT:** BOOKXYZ  
**FROM:** BOOKSELLER  
**TO:** CUSTOMER  
**ACTION:** ((TRANSFER OF OBJECT  
(FROM BOOKSELLER TO CUSTOMER))  
(AFFIRM-EXCHANGE (DECLARE)))

The information C requires to display to B is of an ASSERT type and therefore a DECLARE plan is put into operation and an ASSERT flag is placed in the first slot of the LOGFORM.

**NAME:** DECLARE  
**OBJECT:** NIL  
**FROM:** CUSTOMER  
**TO:** BOOKSELLER  
**ACTION:** (DECLARE (INFORMIF =  
(AFFIRMATIVE = YES, NEGATIVE =NO))  
(INFORMINFO = OTHER))

Both the action of exchange and the utterance affirming this exchange relate to the present and so the tense slot is filled with the flag PRES. The AGENT of the utterance is C and so this slot is filled with PRO PERSON "I". The main action of the AGENT in this utterance is a TAKE action, which is another plan-method.

**NAME:** TAKE  
**OBJECT:** BOOKXYZ  
**FROM:** BOOKSELLER  
**TO:** CUSTOMER  
**ACTION:** TRANSFER OBJECT FROM  
BOOK SELLER TO CUSTOMER

The THEME of the utterance is the BOOKXYZ with PAPERCOVERS having VALUE£15. This is the object with its associated characteristics which is being TAKEn. In natural language the third person singular pronoun "it" could be used to refer to this object. Thus the logical form of C's remaining utterance is:

(ASSERT (PRES (TAKE (AGENT (PRO PERSON "I"))  
(THEME (BOOKXYZ, PAPERCOVERS, VALUE£15)))))

Following C's utterance the transaction is assumed to take place and C has the book she wanted. The recursive action of her ACHIEVEGOAL operation continues to unwind. She has accomplished the BUY sub-goal and ACHIEVEGOAL removes this predicate node BUY from the tree as it has now been satisfied. ACHIEVEGOAL unwinds to the WANT predicate node and the NOTYET flag is removed from the WANT plan-method previously activated.

**NAME:** WANT  
**OBJECT:** BOOKXYZ  
**FROM:** BOOKSELLER  
**TO:** CUSTOMER  
**ACTION:** POSSESS-OBJECT (STATE)

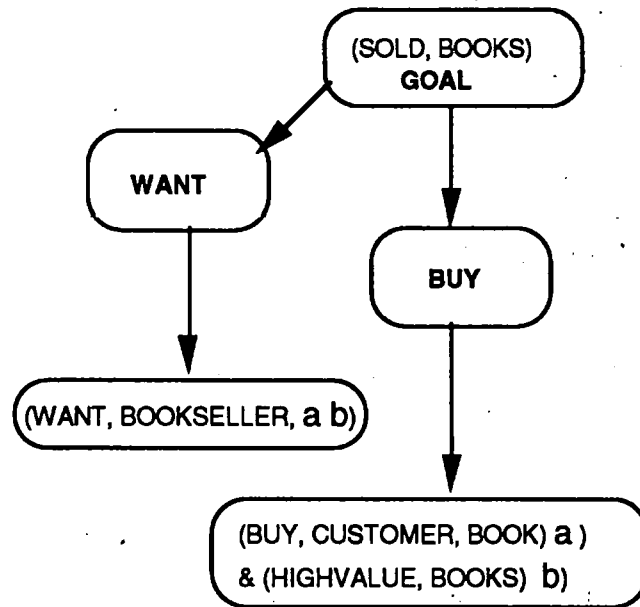
The proposition that formed this sub-goal i.e.(WANTS, CUSTOMER, BOOKXYZ) has now been satisfied. Consequently, the sub-goal of WANT is removed from the tree and ACHIEVEGOAL unwinds to the root node of the tree which is (HAVE, BOOKXYZ). The goal has been achieved, C now possesses the book XYZ and the proposition signifying this fact is placed in C's GBS. The final state of C's belief-set is:

(HAVE, CUSTOMER, BOOKXYZ)  
(VALUE, £15, BOOKXYZ)  
(PAPERCOVERS, BOOKXYZ)  
(HARDCOVERS, BOOKXYZ)  
(HAVE, BOOKSELLER, BOOKXYZ)  
(CUSTOMER, SELF)  
(CUSTOMER, I)  
(BOOKSELLER, YOU)

Similarly for B, all the sub-goals attached to the ~KNOW predicate node have been achieved and therefore this node is removed from B's goal-tree. See Figure 5.8 (4) overleaf.

B's operation of ACHIEVEGOAL unwinds to the BUY predicate node and the NOTYET flag is removed from the ACTION slot of the BUY plan-method. B participates in the exchange of money for BOOKXYZ simultaneously with C.

NAME: BUY  
 OBJECT: BOOKXYZ  
 FROM: BOOKSELLER  
 TO: CUSTOMER  
 ACTION: EXCHANGE (MONEY FOR OBJECT)



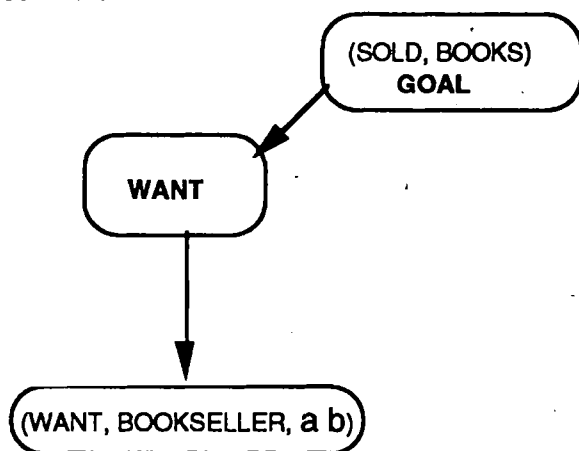
**Figure 5.8 The revised Bookseller's  
Goal-tree (4)**

Consequently, the BUY predicate node is removed from the tree as having been accomplished and the propositions connected with this node are placed in B's GBS as having been achieved. B's belief-set is now in the following state:

(BUY, CUSTOMER, BOOKXYZ)  
 ((KNOW, BOOKSELLER, a ) & ((WANTS, CUSTOMER, HELP) = a))  
 ((KNOW, CUSTOMER) = a, b, c)  
 & ((PAPERCOVERS, BOOKXYZ) = a)  
 & ((HARDCOVER, BOOKXYZ) = b )  
 & ((VALUE£15, BOOKXYZ) = c))  
 (BOOKSELLER, SELF)

(BOOKSELLER, I)  
(CUSTOMER, YOU)

ACHIEVEGOAL then unwinds to the WANT predicate node where the NOTYET flag is dispensed with.



**Figure 5.9 The revised Bookseller's  
Goal-tree (5)**

ACHIEVEGOAL examines the sub-goal attached to the node and identifies that the propositions relating to this sub-goal have been previously satisfied under the BUY sub-goal. The WANT node is removed as having been achieved. ACHIEVEGOAL unwinds to the root goal node which is (SOLD, BOOK[S]) which is now achieved. Consequently, the proposition attached to this node and signifying this fact is placed in the GBS of the bookseller. The final state of B's belief-set is;

(SOLD, BOOK[S])  
(BUY, CUSTOMER, BOOKXYZ)  
((KNOW, BOOKSELLER, a ) & ((WANTS, CUSTOMER, HELP) = a))  
((KNOW, CUSTOMER) = a, b, c)  
    & ((PAPERCOVERS, BOOKXYZ) = a)  
    & ((HARDCOVER, BOOKXYZ) = b )  
    & ((VALUE£15, BOOKXYZ) = c))  
(BOOKSELLER, SELF)  
(BOOKSELLER, I)  
(CUSTOMER, YOU)

Both parties, having achieved their goals, the interaction between them is complete and the dialogue finished.

-oOo-

## **Chapter 6 - Conclusions and Evaluation**

The research aims for this work were identified in chapter one (1.1). There it was stated that this thesis describes research aimed at a theoretical framework for a computer model of natural language dialogue. A preliminary theoretical exploration for a future implementation of a possible dialogue system. Within this context the aim of the study was to make some attempt at understanding how conversation might work and to identify some of the elements that might be required by a model for such an implementation. It was suggested that arising from this, it might be possible to discover characteristics as to how some aspects of conversation might be organised and structured. The motivating principle being the necessity to discover the psychological processes operating in the behaviour of dialogue to facilitate greater ease in man-machine interaction.

It is important to clarify the status of my model in relation to these research aims. The model I am presenting is not an implementation, but is a descriptive model that is animated by a process-oriented approach.

Furthermore, it is not a cognitive model and no claim has been made for cognitive plausibility. It is suggested that the model and this way of thinking might help us to learn or think about what is happening in our minds during the process of dialogue. Therefore, while some aspects of this model may have some psychological plausibility no claim is being made for psychological validity. Psychological processes might bear some similarity to what is presented here or they might be completely different. It is important to remember this caveat in the ensuing discussion of what has been achieved, as aspects of the model are referred to and discussed in terms of human agency. Anthropomorphic descriptions, though contributing to ease in understanding, can be misleading and can help to create an impression of psychological validity that is not being claimed.

In this concluding chapter I propose to discuss and evaluate to what extent the aims have been achieved and what conclusions can be drawn, both from the work and



the overall approach adopted. Firstly, it is necessary to summarise what has been achieved in this study and how the work relates to that reviewed in chapter 3. Secondly, some evaluation will be made and conclusions identified. Thirdly, attention will focus on how the work might be extended and improved and finally how it relates to current developments and trends since the work commenced.

### **6.1 A summary of what has been achieved**

It was suggested in chapter one (1.4) that a model of dialogue needs to account for the roles of both participants to a dialogue and be able to specify the interaction between the participants and how each participant achieves their goals simultaneously in the communicative encounter.

The model presented in this work contributes to such an account and suggests some ways as to how this might occur. It does not focus on only one of the participants to a conversation, i.e. the speaker or hearer, but on both, the speaker and the hearer simultaneously and how these roles alternate as each agent pursues their individual plans and goals. In doing this it suggests how the individual goals and purposes of agents can be formulated from underlying belief and knowledge configurations. The notion underlying the work is that utterances are generated and interpreted as a consequence of participants pursuing their individual goals and purposes.

Agents are shown as having a particular set of beliefs from which plans are formulated to compose utterances to achieve goals that accord with those beliefs. The individual utterances of both participants form a dialogue in which it is shown that both agents achieve their individual, albeit different goals.

This work has been informed by the literature reviewed in chapters 2 and 3. and it is necessary to discuss some of this briefly.

It was stated in 3.1.1 that an assumption of this research is that dialogue is a cooperative enterprise and that this characteristic derives from the underlying rationality of the participants. It was noted there, that Ellis (1979), made a distinction

between ideal rational systems and imperfect human rational systems and that Allwood (1976) and Dennett (1978) also emphasised the imperfect nature of human rationality.

Consequently, I have not attempted to present a formal model where all the beliefs of the agents can be tested for consistency with each other or where logical truths that could be derived from the beliefs the agents hold, appear in their belief systems. This was the approach adopted by Galliers (1989) who accepted the difficulty inherent in such formal systems, of all logical truths appearing among agents' beliefs; which is a characteristic of perfect rational systems (3.1.5). The beliefs the agents have in my model, have been given to them on the basis of what appears to be plausible and could be described in terms of the psychology notion of "common sense". It was not my intention to model a rational system and therefore, it does not show how beliefs are derived rationally and logically from other beliefs. The model assumes a basis of rationality according to the arguments identified in chapter three.

Viewing dialogue as a cooperative enterprise, the model described is informed by a view of cooperation as deriving from self interest (Axelrod, 1984: 6-7) discussed in 2.1.3.2. It was noted there, that Galliers (1989), proposed that conflict has a positive role in maintaining conflict but the view I adopted for this work was that cooperation is a way of diminishing conflict.

A definition of cooperation I suggested (2.1.3.2) includes a number of elements with which the model can be compared, to see how it performs in relation to these.

Participants involved in communicative interaction were said to be involved in a shared process. The model attempts to describe this shared process by identifying and stating the agent's respective sets of interlocking beliefs in the realization of individual communicative goals. The model accomplishes this with respect to the bookseller/customer scenario and also with the management/union negotiations (Appendix 6) but fails to establish this in the teacher/pupils dialogue. (Appendix 6) The reasons for its failure with respect to the latter, appear to relate to the type of dialogue in which the teacher and pupils are engaged in and to the extent the objectives of this

dialogue were shared by the participants. The problems for the model that this dialogue identified will be discussed further in 6.1.7.

Another element of this definition was that the agents maintain the communicative process until one or both of their goals are achieved or considered unsuccessful. The model traces the process of a particular piece of interaction, which suggests how the first part of this element might work, i.e. when both agents achieve their goal. It does not show what happens if goals are unsuccessful or are aborted and therefore compares favourably with only one aspect of this element. The position of the participants in the management/union negotiations is something of a stalemate and does not show how the parties extricate themselves from this impasse. To accomplish this aspect, the model would have to be applied to scenarios where agents have beliefs about aborting their goal(s).

A further element suggested was that cooperation includes the most economic and advantageous way in which purposes and goals are achieved and existing conflict either avoided or diminished or even increased.

The model does not show any particular diminishing or increasing of conflict, *per se*. It may provide some pointers as to how agents' levels of frustration, associated with realising their individual goals, might be reduced but it does not show how interpersonal conflict might be diminished or avoided. The management/union dialogue can be viewed as a scenario of conflicting views but even here, while the model might help to show how the communicative interaction is maintained, it does not show how the inherent conflict characterised by the dispute is either reduced or resolved. At best, it shows how the status quo might be maintained. Therefore, this aspect has not been achieved.

It is therefore necessary to acknowledge, that the discussion of Galliers' views on conflict and cooperation and the alternative view suggested by this work are not as straight forward as the initial discussion might appear to have suggested. Both concepts remain difficult to define and at times it seems that some elements that are

emphasised lead to the eclipse of others which are just as important. It also begs the question as to whether the concept of cooperativity is a factor in all interaction.

Beliefs in the model are represented in a propositional format. Representation of beliefs and knowledge and the reasoning behind abstract propositional representations of belief was discussed in 3.1.4. 1 and 3.1.4.2 and I do not intend to duplicate the discussion again here, except to say that this type of representation chosen for the research appears to work reasonably well in this type of model.

Belief revision and change (3.1.6) is achieved by a 'display' feature rather than by Allwood's other concept of 'manipulation' (3.1.6.) and works by the operation of association (3.1.6.2 ) rather than by the operation of inferences being made from particular configurations of beliefs (3.1.6.3).

The communicative utterances of an agent in the model are 'displayed' to the other agent in a logical form (4.7.1). Though there are structural weaknesses with this aspect of the model, which are discussed in 6.7, this aspect of the model is achieved in a straight-forward manner. It is difficult to envisage how either of the agents in this model could manipulate the configurations of the other without constructing sets of beliefs, goals and plans to achieve such an objective which seems to underline the arguments for the inappropriate use of this concept in this context, as argued in 3.1.6.

The suggestion that belief configurations of agents change as new information is displayed and which is then associated with the belief elements in the receiving agent's goals is a further aspect achieved by the model (3.1.6.2). However, the way in which this operates in the model is by a simple matching process. The more complicated operation of inferencing is not demonstrated and it is likely that the model would have to be considerably revised or added to, to achieve this.

The characteristic of intention (3.1.2), planning (3.1.3), and wants and goals (3.1.5), and how they relate to the work reviewed in chapter 3 are discussed in the following sections.

### **6.1.1 It models the beliefs and goals of participants simultaneously**

The work describes how agents within the context of a piece of purposive interaction come to that interaction with a set of beliefs, motivations, intentions and plans. The resulting dialogue is not formulated randomly but is purposive and structured and the structure of the resulting dialogue-text reflects the participants' plans and purposes.

In ordinary human interaction each participant to a conversation, generally has at their disposal a wealth of information and knowledge prior to any engagement in a piece of interaction. This not only includes beliefs about what they want to achieve from the interaction but also includes knowledge and beliefs about the context in which the interaction is taking place. This will also include knowledge and beliefs about the other participant(s) in relation to gender, status and relationships to do with power and obligation (2.1.3).

Though the model does not attempt to model these aspects explicitly it does suggest how beliefs about the context, and therefore, these related beliefs might impinge upon an agent's goals and purposes.

It shows what might take place between two agents who are given the titles of bookseller and customer, within a constructed scenario when they are ascribed certain specific goals. Within this constructed and imaginary scenario the participants are provided with certain specific goals, elements of which are related to other beliefs they have in their general belief sets. They also hold other beliefs in common with each other. The beliefs and goals of each of the participants are identified and from these it is shown how plans might be formulated for the making and carrying out of specific utterances and how these might be displayed and thus how a dialogue develops.

The description of the process of the model is a linear account of what is happening between the participants and the model shows how individual goal trees are created and how utterances arising from these goal trees might be formulated to produce the dialogue. Nevertheless, this linear process and the construction of goal trees lends a somewhat static character to the model which in itself highlights a major

weakness. Agents need to be able to create plans and adapt existing plans dynamically during a dialogue and the agents in this model cannot do this. It is difficult to see how this characteristic of the model could be altered to accommodate greater flexibility in the construction of plans without fundamental changes.

### **6.1.2 It applies a planning approach to the formation of individual utterances**

Many of the planning approaches described in the literature relate to the planning of motor behaviours or tasks such as the painting of a room or the moving of blocks and the order in which such kinds of task might be accomplished (Pollack, 1990: 78-83). Some planning approaches described, though applied to conversation, generally relate to higher dialogue processes such as conversational preferences or moves such as those employed in argument, debate or the resolution of conflict (Galliers, 1989; Reichman, 1985; Stutt, 1989) or to the performance of actions that have a communicative component. Power (1974), used a planning component in his model whereby Mary and John had to formulate a plan, and agree together on a particular action. Their utterances were an outcome of trying to make and agree these plans. Other planning approaches are aimed at choosing the type of speech act that might be required to make a particular utterance (Appelt, 1985).

The approach of this work is different in that it applies a planning approach to the formation of individual utterances. Using the general framework of the declarative, interrogative and imperative for utterances (4.5), the planning component utilises elements from the participants' belief structures which include drawing on their knowledge about the context and use of plan-methods that relate to that context. Thus the planning component uses information about the mood of the utterance required by the particular sub-goal of the agent being processed, the beliefs the agent might have pertaining to the context in which the dialogue is taking place, and also beliefs about the way in which certain concepts might be used in the making of utterances. The latter

are portrayed in the form of plan-method entities. The characterisation of plans within the model is discussed further in 6.1.5.

### **6.1.3 It suggests how contextual and pragmatic information contained in agents' beliefs might contribute to dialogue**

The model presented in this work is within a context that views people as being processors of information (1.7), but not only this. Participants to a dialogue cannot be viewed simply as having their own beliefs, goals and purposes in a vacuum but must be seen as operating within a wider social context (2.1.3). It follows from this assumption then, that participants to any interaction must be viewed as having beliefs and knowledge about their immediate context and also a much wider world context or view which will impinge on their participation in any conversational encounter. Information available to agents within an encounter but which is external to them has to be interpreted and stored in their memories and belief systems.

The weakness of many approaches to the study of language and conversation is that it is often compartmentalised into the three areas, of syntax, semantics and pragmatics (4.1). It was noted in chapter 4 that Allen devised a system whereby the syntactic construction of language was represented by a logical form, the latter which was used as an intermediate representation between the syntactic form of a sentence and its contextual interpretation (4.7). That is:

Syntactic construction

Logical form

Interpretation in context

Any decisions that require contextual knowledge in Allen's model, are not made in deriving the logical form. Instead, information from the sentence structure is recorded in the logical form for use later by a contextual analyser.

The approach that has been adopted in this work is that the immediate context as well as the wider context of a speech situation are known to the respective agents and form part of their belief systems, otherwise none of these contextual elements could be used in the process of conversation.

Information about the context in which the dialogue is taking place is contained in the beliefs of the agents and therefore informs and influences the belief configurations of the agents involved. It is from these belief structures that they formulate their utterances and will choose syntactic constructions that reflect what they want to convey in accordance with what they believe.

As previously indicated, (6.1) beliefs of the agents in the model are represented in an abstract propositional form (3.1.4.1) and the specific formulation used in the model is explained in 4.3 & 4.3.1. Individual elements or concepts comprising these belief propositions are then used in the construction of the agent's goals, plan-methods for realising these goals in practice, and the construction of context-frames. In this manner the model attempts to incorporate aspects of agents' beliefs about the wider context and how things are actually achieved by agents. Elements from the agent's prior set of beliefs, their goals, plan-methods and context-frames are used to construct a logical form prior to an utterance being made, which is then used to compile the syntactic form of the utterance.

A major weakness of the model is that it does not show how agents make the link or draw inferences between beliefs in their general belief-sets and the context. This deficiency is overcome by the use of context-frame structures that contain much knowledge that is not defined specifically in the agent's general belief sets. While this device works for the model it blurs the distinction between the beliefs the agent has that are specified in a propositional format and other beliefs or knowledge about the context that are being specified in a frame-like construct. This inconsistency in the presentation of different kinds of beliefs is a flaw which might be possible to correct by adopting a single format for the presentation of all beliefs and knowledge. It is a difficulty that relates to belief and knowledge and how this should be represented. A



similar discrepancy occurs with the plan-method construct which is discussed in 6.1.5.

#### **6.1.4 It shows that agents pursue their own individual goals and only adopt the goals of the other agent if this suits them**

It was noted that a widely accepted assumption within AI and the related literature, is that for conversation to be maintained, at least one of the agents need to accept the communicative goals of the other, otherwise the conversation will not work. This was discussed in 2.1.3.2 and I do not intend to repeat the discussion or arguments here. Nevertheless, in the discussion concerning the characteristic of cooperation it was argued that the behaviour of participating in conversation is a cooperative activity per se and does not require the explanation that one agent adopts the goal of another for it to be maintained.

Other examples, that involve human interaction which require the cooperation of the participants, such as some games, were identified to illustrate this point (2.1.3.2). It was argued in 2.1.3.2 that conversation is a cooperative activity of itself and that this was maintained by factors such as 'face' and social sanctions, status and power relations, the need to pursue present as well as future goals and the important necessity of minimising conflict (2.1.3).

This provides an alternative view and suggests that participants to a conversation can have very different goals from each other but still participate in conversational interaction which by its nature can be cooperative. Furthermore, that it is by having different goals, participants maintain motivation to pursue or discontinue the conversation.

The model shows how the bookseller and customer have different goals and objectives to achieve and through the process of identifying each others goals and purposes, dialogue is produced and their respective objectives achieved.

For this purpose, the goals of the agents are prescribed. It may have been useful to specify how these originated from the agent's belief-sets but it was not a purpose of

this work to research the character of goal formation. Goals are specified in a propositional format similar to beliefs (5.2.1) and on the surface, appear to be indistinguishable from beliefs. They are distinguished by the action-type elements that form the predicates of the belief propositions. With respect to the bookseller the elements SELL, WANT and BUY distinguish this set of belief propositions as being their general as well as specific goals for this dialogue and with respect to the customer it is the elements HAVE, WANT, and BUY.

Whether the inclusion of such action-type entities in a belief proposition would always constitute such a belief-proposition as being a goal, has not been tested exhaustively and therefore, this method of distinguishing between beliefs and goals could be flawed. Nevertheless, intuitively, goals do appear to possess elements of an intentional quality to them and the use of action-type entities to distinguish goals from beliefs serves to suggest how close a link there might be, between an agent's beliefs and the formulation of goals from those beliefs.

#### **6.1.5 It focuses on speakers and hearers intentions and shows how these might be realised as sub-components of plans**

Attention was drawn to the comments of Grosz and Sidner (1986: 175) and also Cohen (1984: 97) who believe that attention must be given to the 'intentional structure' of language and conversation (1.4). The subject of 'intention' is a philosophical one and the literature relating to it is considerable. However, it is not possible to ignore this aspect and some reference needs to be made to the concept in the use of conversation, particularly in any model that utilises a 'belief' component. A major difficulty facing any researcher in this area is deciding what intentions actually are and how they can be represented.

This work is informed by the writings of Bratman (1987) who views "plans as intentions writ large" (3.1.3.2). This is a useful way of dealing with intention and lends itself to an approach whereby intentions can be described and modelled as sub-components of plans which has been attempted in this work.

The agents possess a certain set of beliefs about the world which provide them with motivation to achieve certain goals. These motivational elements of their goal-beliefs, discussed in the previous section, help to form their communicative goals in the dialogue. They are also used to formulate their goal-trees for the production of utterances. This motivational element of the goal-beliefs can also be viewed as having an intentional ingredient but this is more accidental than by design. The intentional component of the model is built into the plans and the plan-methods.

Plans within the model relate only to the mood of an utterance and how these are to be formed (4.5). That is, they relate only to the most fundamental mood choices in English which are declarative, interrogative and imperative. Although plans are distinguished theoretically within the model (4.5), in practice, they are formulated as plan-methods and therefore are indistinguishable from other plan-methods such as **HELP**, **BUY**, **SELL**, **EXCHANGE**, etc., (Appendix 2). Plans, intuitively, suggest as being somewhat large psychological entities that might contain several elements. With this in mind, the plan element within the model was defined in terms of more primitive entities by formulating them as plan-methods. The model does not have a mechanism for creating more general plans.

It is in the context where plans to achieve goals can be more easily specified that the concept of recursion as used in the model is a useful one. In order to achieve a major goal or carry out a plan it may be necessary to carry out a host of sub-plans and sub-goals which might emerge or change dynamically in the course of interaction. Recursion is a concept that helps to explain the process whereby agents are able to pursue their ultimate goals and to maintain interaction until either one or the other parties achieve their goals or they change their goals and call a halt to their discussions.

Plan methods are dynamic constructs and achieve action within the model. They have links with associated plan-methods through their **ACTION** components. Sometimes, the operations of several plan-methods are required to bring about an action or an utterance. Plan-methods are the intentional component of the model and

can be likened to the sub-components of plans suggested by Bratman (1987). Furthermore, as both agents possess the same set of plan-methods, the recognition of the plan-methods or an element of the plan-method the other agent is using, is achieved by a simple matching process.

Plan-methods are a simple way of providing the agents with knowledge of how to do things. General beliefs are represented in an abstract propositional form as are the goal-beliefs but knowledge about the context and knowledge about how to achieve things are represented in frame-like structures that have a dynamic element attached to them. The weakness of this approach is that the use of different representations to represent different kinds of knowledge can be confusing and criticisms made about the context-frame structures, can also be directed at the plan-method structures (6.1.3). The strength of this approach is the dynamic nature of these frame-like constructs.

A further disadvantage is that context-frames and plan-methods are also referred to as belief structures. They each contain and employ elements of beliefs from the agent's propositional belief formats which tend to blur the boundaries between these entities. Once again, this points to the difficulty associated with the representation of knowledge and belief and the ease with which some kinds of knowledge lends itself to be represented in one way and other types of knowledge and belief to being represented in another. Difficulty with more precise definition has been encountered, especially when these entities tend to share similar elements with each other.

Representing intention in this work has not been without its problems and no claim is made that this has been achieved. It contains intentional elements, and these, as has been noted, are defined as plan-methods. Though an intention may be a psychological entity in its own right, distinct from a belief or plan or even a sub-component of a plan, what does become evident is the intentional ingredient or quality that appears to be inherent in beliefs, goals and plans and is difficult to distinguish from these entities. Motivation itself and the goals which are its objects appear to be multiple in character. An attempt to distinguish a separate entity of intention may be a somewhat forlorn

exercise as it may be an emergent quality arising from other entities and unidentifiable apart from these.

#### **6.1.6 Comparisons between this research and Power's work**

Power's (1974) work is quite unique within the literature and his ideas have informed this research. Attention has been previously drawn to the fact that his work attempts to model both speaker and hearer in their alternating roles in the form of two robots within a model of conversation (2.2.2). It is therefore somewhat surprising that his work has not attracted more interest and debate than it generally has. This may be because of some of the inherent difficulties in modelling conversation that he helped identify and also the scale of such a task.

This research complements his in a limited manner. Firstly, it focuses on the beliefs of agents and how these are used to mediate between their perception of the world and their interaction in it by way of making utterances. What the agents believe become elements in their goals which are used to formulate their sub-plans in pursuance of these goals and which are then reflected in the content and structure of their utterances.

Secondly, an attempt has been made in this work to apply the model to more natural and life-like scenarios than that of Power's robots. The robots within Power's model have a very limited view of the world that is tied to a few specific objects and to rules relating to those objects and how they are to be used. What has been attempted here is to apply the model to more natural dialogue scenarios such as the task oriented dialogue between a customer and a bookseller; the negotiations between a union and management and a teacher and her pupils.

An important focus for the model was not the specific sets of beliefs that relate to each of the scenarios, but the processes by which the beliefs are used to achieve conversational goals. Given a different scenario, the resulting dialogue of agents with different sets of beliefs should reflect the beliefs and structure of those different goals and purposes but the processes and structures by which those utterances were

achieved should remain the same. However, the attempt to apply the model to more fluid dialogues, other than the bookseller/customer scenario, was not successful as was initially anticipated and some of the difficulties encountered are discussed in the next section.

#### **6.1.7 Extending the model to other domains**

To illustrate the model in operation an example scenario had to be selected and the one chosen was the type of interaction that might take place between a shop assistant and a customer concerning the purchase of a particular book. The reasons prompting this choice being that this type of interaction is both familiar and natural but also structured and constrained by the task and objectives of each of the participants. Any 'sales' type of scenario could have been selected for this purpose because it is a category of human interaction that places some constraint on the possible conversational options for the achievement of such a task.

One of the main ideas behind the model is that utterances and dialogue stem from an agent's specific set of beliefs and goals relating to some particular object. Therefore, if the agents within the model are allocated beliefs and goals relating to other scenarios, the resulting dialogue should reflect the structure of those goals and beliefs. It was necessary to test this idea on more fluid dialogues and some attempt has been made to apply the model to two other scenarios, the result of which, throws some doubt on the possibility of extending it to other domains. These other scenarios are the negotiations between union and management representatives and the interaction between a teacher and her pupils (Appendix 6). Both these scenarios are more fluid and less structured than the bookseller/customer scenario and serve to identify weaknesses within the model and the possible necessity for changes and/or modifications.

For instance, a major weakness is identified in the compiling of the agents' goal trees. Whereas in the interaction between a customer and bookseller the overall goals of each could be clearly defined in explicit well-developed goal-trees (5.2.3) this was

not possible for the management and union negotiators or for the teacher/pupil interaction.

While each side in the management/union negotiation and the teacher in the teacher/pupils scenario, had overall goals they wished to achieve, it was difficult to identify any interim or sub-goals they might achieve on the way to achieving their ultimate goal. Both sets of negotiators in the management/union scenario, needed to chip away at each others arguments and responses. They might have started from opposing positions and needed to expose the flaws in each others arguments. This could either have been anticipated beforehand and built into their sub-goal strategy, but with the risk of anticipating wrongly, or more likely, could best be dealt with while the negotiations were being conducted.

The pupils in the teacher/pupil scenario did not know what they were going to be discussing until the teacher introduced the topic and even then, this might have been a completely new topic to them and involved them in the learning of new concepts. Therefore, it was not possible for them to have any general goal to achieve from this interaction prior to its commencement. Not having any overall goal they would not have any sub-goals to achieve either.

This might suggest that a goal-oriented approach to dialogue cannot be applied to this sort of interaction and on the surface this might seem to be the case. If this is so, then the preceding theory that utterances are the sub-plan components of communicative goals that derive from agents' beliefs, is implausible and needs to be abandoned.

However, an assumption behind this work is that utterances are the outcome of intentional behaviour and that intentional behaviour is not random but is rational and planned. Therefore, this assumption needs to be applied to the interaction of the pupils in the teacher pupil scenario.

The explanation for their rational responses to a topic they are beginning to learn about can only be understood by ascribing to them a general goal of cooperating with the teacher. The pupils are likely to be in a lesson that they have to attend, although

they might enjoy being there, and could be viewed as passive participants to the interaction. On the other hand, they could be eager learners and active participants. Whether they are passive participants or active learners, it is one of those dialogues that reveals the nature of the power relationships that can exist between participants in an interaction and the status and obligations these relationships might represent.

Though it may not be possible to identify any communicative goals for them to pursue, prior to the commencement of this interaction, these can be seen to emerge in response to the teacher's demands on their thought and attention. The pupils are required to respond and they do so in a thoughtful and intelligent manner according to their beliefs and what knowledge they have available to them. Though the pupils are active in the dialogue it is not one that has been initiated by them but they cooperate and engage with the teacher, which behaviour can be interpreted as intentional and therefore goal-motivated behaviour.

They cannot be said to adopt the goals of the teacher as they don't know what these are and for the reason that they are learning new information about the concept 'capital punishment'. The general goal of the pupils then, can be interpreted as cooperating with the teacher's questions and answers because they are involved in a cooperative activity per se. If they didn't cooperate, it is likely they would be open to sanctions by the teacher for uncooperative behaviour. Their 'conversational goals' are formed and made in response to the teacher's questions.

This suggests that goals and beliefs are changing, and or emerging, in the process of interaction and only an extremely dynamic system could model this characteristic. Even in the bookseller/customer scenario, though the goal-tree for the bookseller was identified quite explicitly it is likely that the more explicit sub-goals identified would only emerge as the dialogue progresses.

Any plausible model of dialogue would have to capture this dynamic and emergent characteristic of intentional behaviour in conversation.

It also suggests that different types of interaction require the use of different strategies. There are some types of interaction where the goals involved can be easily



specified as can the plan and sub-plans to realise the goal. Other types of interaction suggest that the goals for each utterance and the planning of the next utterance take place as the interaction proceeds. This problem has been previously noted (6.1.1) and relates to the necessity of being able to create plans in a dialogue dynamically. The difficulty with any attempt to represent these processes in a more formal manner is that it ignores the characteristic of human consciousness and the ability of humans to think and reflect on what they are saying and what is being said to them.

## **6.2 Evaluation**

It has been suggested that a characteristic of a good theory is that it clarifies the most significant factors of a process which make certain patterns predictable (Best, 1986: 185). A method frequently adopted is to develop a formal system for the theory and then to argue that the organizational principles of the formal system are either analogous to, or even in some sense identical to, the organizational principles of the process being modelled. In the brief discussion of Black's (1962) comments about the sorts of models used in research (1.8), it was concluded that the type of model being presented in this work was a theoretical model.

One of the things that Black said about the use of this type of model was that it was more "a way of talking" rather than the building of an actual model and that imagination could be a useful and valuable ingredient in this task.

This work has been influenced by the latter approach. It has involved an attempt to construct a theoretical but imaginative model of natural language dialogue that captures some of the salient features of the processes involved. It has been constrained by the necessity to describe the model in terms of process with a view to a possible future implementation in a computer program. It is not an implementation, rather is it a descriptive model that is animated by describing it in terms of process.

Following the summary of what has been achieved in the previous sections, it is necessary to provide some critical evaluation and this is done on the basis of how closely the model adheres to either of these two dimensions.

### **6.2.1 Strengths of the descriptive approach**

The strength of the descriptive approach allows for the dual nature of dialogue to be described which includes language production as well as understanding. These are both large areas for research in their own right but a model of the processes of dialogue needs to encapsulate both and the scale of what is involved possibly militates against developing a formal system.

A further strength of this approach is that it allows for the entire process of dialogue to be described. That is, from the formation of agent's goals which are part of their belief system; to the formation of plans to achieve those goals; to the formation of structures which include the components of mood, tense, belief elements and contextual cues prior to the making of utterances. It also allows demonstration of how each utterance of each agent dovetails with the utterances stemming from the goals of the other participating agent(s). In this way the model suggests how information given in a reply but not requested, nevertheless furthers the goals of the agent for whom this information is useful.

Another strength of this approach is that it helps show how the beliefs and goals of the participating agents might relate to each other and how these in turn might relate to the dialogue that is produced. The resulting structure and organization of the dialogue-text reflects the beliefs and goals that motivated it and can only be interpreted and understood in this context. It suggests therefore, that to properly understand what is going on in any dialogue or conversation one would need to know what the beliefs, goals, purposes and motivations of the individual participants were. Without this knowledge any assumptions we might make, at best can only be subjective.

### **6.2.2 Advantages of the formal approach**

A major criticism that could be levelled at the descriptive approach and therefore against this work is one I raised in relation to the writings of Merleau-Ponty in chapter one (1.7.2). It could be said, and possibly not without some justification, that having warned against the difficulty, I myself have not avoided it and that the approach

adopted in this work is too subjective, being characterised by the use of too much imagination and lacking in essential rigour. Black did identify a major difficulty with this approach, previously identified when he said:

"a strained and artificial description of a domain sufficiently known otherwise" (Black, 1962: 237)

An advantage of a formal approach has already been noted in 6.2. By developing a formal system for a theory it is possible to argue that the organizational principles of the formal system are either analogous to, or even in some sense identical to, the organizational principles being modelled.

A formal approach to modelling dialogue requires a formal language such as a logic which possesses a precise semantics. Every expression in the language is determined by its semantics. Sentences in the language are derivable from the set of axioms and well formed formulas of the logic and should be a valid consequence of those axioms and formulas. That is, other logical conclusions might be derived from them.

This has a number of advantages. One consequence of such a formal system is that there can be no ambiguity in interpretation. Another is that the inference procedures can be checked for their soundness. Such a system that has a precise semantics to which all expressions must conform, could provide a rigorous basis for testing paths of reasoning in the formulation of utterances in dialogue.

The major drawback with this approach has been previously discussed (4.3 & 6.1). This is that it makes the assumption that agents are ideal knowers and ideal reasoners. From the conclusions drawn from the discussion concerning rationality it was decided that human rational systems were not ideal or perfect rational systems and therefore this formal approach was not pursued.

In an attempt to avoid the pitfalls identified by Merleau-Ponty and Black, use has been made of the inherent discipline required by the demand to develop a model in

terms of process as this was seen to be valuable and a useful constraint for the work and to keep imagination within acceptable bounds. Therefore, the model and the 'hand-simulation' of the model is described and presented as a process and some attempt has been made to show how the most significant components of the model might relate to each other in an integrated system.

It is therefore necessary to view this work as being a preparative enquiry for a future implementation of the model in a computer program. It can be viewed as the preliminary development of some aspects of a theory of natural language dialogue that needs to be refined and developed by the rigour inherent in programming.

However it is also necessary to note that a computer model is not necessarily a formal model. It might be possible to build a computer model that does what its creator required it to do irrespective of how humans do it or it might be used to draw conclusions about the way in which human processing works, without necessarily claiming that the processes are exactly the same in both cases. On the other hand, an aim could be to construct programs that are functionally equivalent to a psychological theory where every thought process is specified in the program by a corresponding process. The most usual method of testing these models is to run the program to see whether the behaviour of the computer mimics or simulates that of the human being. Such simulations involve the double discipline of explicitness and testing which has been discussed in 5.1. A formal model or program is a symbolical system that leaves no room for doubt or misinterpretation whereas a computer model is generally a representation of a situation.

The model presented in this work is not a formal model and the extent to which it is a computer model needs to be clarified. It is not a model that seeks to simulate every process which might be involved in the production of natural language dialogue. Therefore, it does not claim to be a model of the human cognitive processes that might be employed in this behaviour. It is rather a model from which to draw conclusions as to the way human processing in dialogue might work. Any psychological model of

natural language dialogue would probably need similar knowledge structures and processes that are suggested in this model.

The aim of building a model of natural language dialogue is to include those features of the process which are important to it. I have attempted to do this in this work which identifies some of the processes that might be required for such a system. A major weakness is that without being able to show how the components work together in a functional system it is not possible to test the model on the chosen dialogue scenarios, yet alone on more complex dialogues.

### **6.3 The simulation of the model**

The description of the simulation of the model is of necessity, a linear description. This identifies a serious limitation, as an appropriate model of natural language dialogue would have to capture the simultaneous processing of beliefs and goals of both participants. For example, the process `COMPILECONTEXT` comes too late in the process. It is likely that cues from the context are already available to agents at the outset of any interaction. Similarly, it is possible for the process `CONSTRUCTLF`, to identify an element that has two meanings associated with it, i.e. the bookseller might be using the concept `SELL` but the obverse of this concept, `BUY` is required by the customer. (see also 5.2.7 and the discussion of `HELP` and whether the state or the action was required). This is not very plausible as a human processor is likely to derive the sense of the meaning required from the context with some immediacy. A minimal requirement for a system of natural language dialogue would therefore be parallel and simultaneous processing.

Furthermore, a hand-simulation of any model is an inherent weakness. Although the literature identifies others who have adopted this approach (Reichman, 1985: 108) it remains a less than satisfactory method and is much less plausible than a working program. Such a process enables any inherent weaknesses within the processes to be glossed over or to remain unidentified which would not be possible in a working computer program. Some of the ideas in this work could be implemented in a

computer program and is one of the ways in which the work could be extended which is commented on below in 6.7.

In considering how to program a problem of this nature it was envisaged that some aspects of the conversational process might be captured in an object oriented approach to programming. The major components of the model such as the agents' beliefs, goals, plans and plan-methods can be envisaged as objects and using the characteristic of inheritance and the ability to pass messages between objects it might be possible to capture some elements that might contribute to a plausible model of dialogue.

#### **6.4 What the model does not deal with**

It does not deal with ambiguity, types of assertions such as passives, nor with ellipsis, anaphora, agrammaticisms, figures of speech and numerous other language characteristics and devices.

Speech is accompanied by gestures, intonation, pauses, hesitations, false starts, changes of focus and subject and the model has nothing to say about these characteristics although change of subject and focus could relate to the change in goals of the participants. Nor is any comment made about the non-verbal aspects of conversation although the model suggests that such information would have to be represented in the belief and knowledge structures of the participating agents.

In justification, the model never attempted to deal with these issues but what it did set out to deal with was the way in which utterances of two or more agents might be formed in relation to particular sets of beliefs and goals within the context of a limited domain. Despite the qualifications and criticisms, the model does have something to contribute to our understanding of this process as identified above.

#### **6.5 Possible objections to researcher constructed dialogues.**

Brown and Yule make a distinction between 'sentence' and 'utterance' (1983: 19ff). They suggest that it is reasonable to propose that features of spoken language should be considered as features of utterances and that features typical of written

languages as being characteristics of sentences. Furthermore, they clarify what they mean by the term 'sentence' by drawing attention to the distinction Lyons makes between 'text-sentences' and 'system-sentences'. Lyons describes the latter in the following way:

"...system sentences never occur as the products of ordinary language-behaviour. Representations of system-sentences may of course be used in metalinguistic discussion of the structure and functions of language: and it is such representations that are customarily cited in grammatical descriptions of particular languages" (Lyons, 1977: 31).

Brown and Yule suggest that there are important methodological differences involved in the two approaches. The grammarian tends to concentrate on a particular body of data in an attempt to produce an exhaustive but economical set of rules which will account for all and only the acceptable sentences in his data. On the other hand, the discourse analyst treats his data as the record of a dynamic process in which language was used as an instrument of communication in a context to express meanings and achieve intentions. In their role as discourse analysts, Brown and Yule employ the term 'sentence' in the sense of 'text-sentence' because they are overwhelmingly concerned with ordinary language behaviour.

The purpose of this discussion is to demonstrate that both uses are legitimate and Gazdar has given something of an overt commitment to the constructed-data approach:

"I shall assume....that invented strings and certain intuitive judgements about them constitute legitimate data for linguistic research" (Gazdar, 1979: 11).

Because of the wish to account for the mental processes that might be involved in the language producer's production of utterances, this work adopted the constructed-

data approach to the problem. In fact, this approach seems the only plausible way of proceeding where it is necessary to identify the beliefs, plans and goals of the participants. Because it is not possible to get at these elements objectively in 'ordinary language behaviour' for the reason that we cannot get inside another person's mind, it is necessary to construct the data. As well as constructing the dialogue it is also necessary to construct the beliefs and goals that might produce the particular piece of dialogue that has been constructed.

Not only is this a legitimate way of proceeding it seems to be the only way of proceeding in this context.

## **6.6 Conclusions that can be drawn from the work**

From the preceding discussion it is suggested that the following conclusions can be drawn.

- any plausible model of dialogue will have to account for the language behaviour of both participants and not only one of them.
- such a model would need to demonstrate how the beliefs, goals and plans of the participants were represented for each agent and how they interlocked together to produce dialogue.
- furthermore, such a model would need to identify how the beliefs, goals and plans of the participants contributed to the choice of semantic, syntactic and pragmatic options available to speakers and hearers in their alternating roles.
- the model would also have to account for how contextual and pragmatic cues were mediated by the participants and represented in their belief systems. Also, how cues of this type were added to the belief system in the course of the dialogue.
- it would also need to identify how utterances comprising all these elements are put together.
- furthermore, any plausible system of dialogue would need to capture the dynamic nature of goal and plan creation as the dialogue ebbs and flows.



- a plausible model of dialogue would also need to account for conversational interaction per se and not just particular types of interaction.
- it would also have to capture the simultaneous and parallel characteristic of processing information.
- lastly, it would need to identify interpretative processes and demonstrate how feedback influences and changes goals, objectives and existing belief structures.

Although the model falls far short of offering any solutions to such problems it has made some tentative suggestions as to what might be involved. It is now necessary to examine how the model might be extended and improved.

## **6.7 Possible extensions and improvements to the model**

The methodology chosen for this work was that of an iterative process described in 5.1. By performing a series of steps repeatedly, successive approximations can be made until the desired result is achieved.

It was noted in 5.1 that a dialogue scenario had been selected from a particular domain, the first stage in this iterative process. Then, a hypothesis was made as to how this particular piece of dialogue might be achieved and what processes might be involved (Chapter 3). A third stage of this process was to think of further scenarios to see whether the proposed model could cope with them as this was considered to be a useful way to refine, generalize and extend the model (Appendix 6). The fifth stage was to describe the model using a language independent of the programming language used to implement the model.(Chapter 5). It was also noted in 5.1 that this methodology had been modified, in that the fifth stage had been employed to describe the model but no programming of the model had been carried out. (the fourth stage).

The way in which this research relates to this methodology is the application of the first three stages of this iterative process to refine, generalize, extend and modify the model and the ideas behind it. The selection of an initial dialogue scenario and the making of an hypothesis as to what the processes involved might be, formed a major part of the early work which, initially, seemed quite promising. Application of the

third stage, the introduction of further dialogue scenarios to see whether the model could cope with them, has already been discussed in 6.1.7 and the flaws and difficulties that this stage identified, as well as the implications for the success of the model have been noted.

The following discussion identifies further areas where improvements and modifications could be made by the application of this iterative process of improving the model.

ACHIEVEGOAL is the process that can be viewed as the executive function of the model. It is within this process that the other functions are implemented and which draw on the necessary beliefs and knowledge to construct the utterances. The function ACHIEVEGOAL uses CREATEGOALTREE to construct a GOAL-TREE after which it uses UTTERANCEPLAN to CONSTRUCTLF, a logical form, using the function COMPILECONTEXT in this process. It then displays the logical form of the utterance to the other agent. This process has a number of inherent weaknesses that need to be identified.

The function ACHIEVEGOAL takes information from the general belief set (GBS) and the specific belief set (SBS) of the agent and from this information constructs a GOAL-TREE. ACHIEVEGOAL then processes this GOAL-TREE, sub-goal by sub-goal utilising the other functions UTTERANCEPLAN, COMPILECONTEXT and CONSTRUCTLF to do this. It will be evident from this description of ACHIEVEGOAL that the process has a great deal of work to do but the model does not specify how this work is to be accomplished in any detail. This executive process was described as being a number of operations but these were not identified and this is a considerable weakness.

ACHIEVEGOAL has too much work to do and too many operations to carry out that remain unspecified and these operations need to be identified in greater detail. One way in which the model could be improved is to make ACHIEVEGOAL an executive process only which uses more specified processes to accomplish its task. For instance, ACHIEVEGOAL uses the process CREATEGOALTREE to construct a

GOAL-TREE which it then proceeds to process but how it does this is not specified. Another process is required to process the GOAL-TREES of the agents under the control of the executive function ACHIEVEGOAL.

Another weakness is associated with the GOAL-TREES themselves, which becomes evident in the application of the model to less structured dialogues such as the management/union and teacher/student scenarios .

In the bookseller/customer scenario the sub-plans for each participant were made explicit and were shown to be part of the agents' goal-trees constructed prior to the commencement of the dialogue. These sub-plans related closely to the logical forms from which the individual utterances were compiled and each contributed to a sequence in the dialogue.

The creation of goal-trees in the management/union negotiations exposes a possible weakness in this process and might suggest that either the concept is flawed or its representation is inadequate.

Both managers and union negotiators have an overall goal they wish to achieve. The union's goal is to persuade management to include a particular clause, favourable to their members, in their new disciplinary procedure while management's goal is to persuade the union to accept the procedure as it stands. The formation of the goal-trees of the agents participating in this exchange differ considerably in structure to those of the bookseller and customer. In the former scenario, both sets of negotiators are pursuing an argument and it is the stages in their argument that form the sub-plans in their goal-trees. However, what follows from this is that both sides make an assertion at the outset of their negotiations which is followed by further assertions from both sides. Each contribution to the dialogue is an assertion and both sides continue to make these until the discussion reaches a stalemate with neither side being able to convince the other of their arguments. Sometimes it is even difficult to categorise some of these assertions either as statements or questions as they have elements of each in their content.

A major difficulty for the model is that the sub-plans of the management and union negotiators' goal-trees become a list of sub-plan assertions attached to the main goal. In reality, it would be difficult to specify these prior to the dialogue as they would only emerge and be identified as the discussion progressed. Nevertheless, using a constructed-data scenario it is possible to show how such a discussion might take place with a list of assertions as sub-plans attached to the main goal.

A difficulty remains as to how this might otherwise be dealt with and exposes the necessity for being able to show the dynamic nature of such a process. What it does seem to suggest is the complexity and numerous ways the human mind has at its disposal of dealing with different forms of interaction. How in one scenario a particular strategy might be used and in another, a different strategy and sometimes, differing strategies in the same scenario. The number of strategies available are likely to be large, flexible and highly interchangeable depending on the communicative goals and context.

Another area where considerable improvement needs to be made is the aspect of feedback of information. The model implies that this takes place by utilising a host of servant functions which do the passing of information and messages about the system. However, this needs to be defined in a more specific manner.

COMPILECONTEXT which is the process used by UTTERANCEPLAN to obtain information about the context for use in the logical form, is able to obtain information from the belief set of the agent which includes beliefs both from the GBS and also the SBS. How it does this is again unspecified and this needs to be identified in greater detail.

A further problem for the model is the way in which the INTERPRET process is used. INTERPRET makes an analysis of the other agent's LOGFORM which has been displayed. It uses the COMPILECONTEXT process to do this and once the information from the agent's LOGFORM has been processed it calls its ACHIEVEGOAL function to process or continue processing its sub-goals in order to make further utterances. INTERPRET is a process that sits uneasily in the model and

in many ways seems detached or even added to as though it were a necessary appendage. It might be possible to incorporate this process more closely under a reorganised executive function of ACHIEVEGOAL.

Though it is necessary and useful to discuss how the model might be extended and improved, this sort of discussion is somewhat limited in value while it remains a theoretical model at this stage of development. While the description may have some plausibility, it remains a theoretical description only and what is required is a functional and operational implementation of the model.

An obvious extension to the work would be the compiling of a computer implementation. This would help to identify weaknesses in the present presentation and allow for the testing of less structured dialogues. Furthermore, it would assist in refining the theory and possibly lead to changes or replacement of existing structures or the creation of new structures. It might then be possible to make adaptations to the program by simulating only one of the agents and allowing a human operator to be the other agent. This would help test the robustness of the program, the overall purpose being to examine whether the theory could be developed further or whether it should be abandoned.

## **6.8 The relation of the work to current developments in the field**

In 1986, George Kiss in a very thorough survey report, High-Level Dialogue in Man-Machine Interaction identified a number of directions for further research which he saw as being important in making contributions towards implementations of high-level dialogue in Human-Computer Interaction. Among the strands he identified were three that are connected with the work presented here. They are:

1. characterisation of agents;
2. the computations underlying action, particularly the relationship to goals, desires and values;

3. the effect of relationships between agents on the computations determining action, particularly in the sense of cooperation and conflict between agents.

This present work can be viewed as an exploratory and preliminary stage of some aspects of a theory of natural language dialogue that might be further developed in a computer implementation. It has been motivated by some of the broader research directions identified as being necessary by Kiss.

In summary, an attempt has been made to characterise some of the characteristics of agents in the process of natural dialogue in line with his first research direction. It is an attempt to explore the way in which agents might intend and plan individual utterances and also identify the intentions and plans of other agents in their utterances. Furthermore, and following Kiss's second strategy, a purpose of this work is to show how goals and desires of agents might be related to their beliefs and how these might be realised in particular utterances in pursuance of those goals and beliefs. Thirdly, it is a model of natural language dialogue that is viewed as taking place within a context of cooperation and conflict but which differs from the more usual ideas about the nature of these concepts presented in the literature and therefore presents an alternative view. Therefore, the work is within these research directions identified by Kiss and makes a contribution to them.

It is also within a general framework which includes areas of study relating to intention, planning, plan recognition and speech act theory. All these remain a current focus of attention and concern for researchers at the present time. Indeed, it is these subject areas that continue to provide the field with its main obstacles and problem areas.

In March 1990, a symposium was held in which many of the leading researchers in the area of communication came together to discuss, what they believed to be the major issue facing researchers. This was identified as being the nature of intentions in communication. This symposium brought together many of the authors whose work

in the 80's has been discussed in the preceding pages. The collected papers from this symposium, as well as evaluations and criticisms of them, have been published under the title Intentions in Communication (1990).

What is significant about this collection of papers is that it serves to summarise much of the research done in the previous decade and to identify many of the problems that have emerged. At the beginning of the 90's most of the major problems remain and much present research continues in the major areas identified above.

In their introduction to the papers, Cohen, Morgan and Pollack make a salient remark in commenting on the following dialogue:

"Where are the chuck stakes you advertised for 88 cents per pound?" to which the butcher replies, "How many do you want?" (Cohen, Morgan and Pollack, 1990: 1)

Cohen et al says,

"Despite all the theorizing about language that has been done by linguists, philosophers, computer scientists, and psychologists over the past thirty years, this simple interchange is magical."

The significance of this comment is the admission, that after all the effort of the last thirty years, we still cannot identify how the butcher's reasoning explains the dialogue. Nevertheless, what the writers do identify is that central to this dialogue, as to every other dialogue, is the nature of intention. Cohen et al point out that there is not yet a complete theory of the role of intentions in communication, that is:

".....one that explains how intentions contribute to linguistic (as well as nonlinguistic) meaning, how smaller intentions combine to form

composite ones, how in making an utterance a speaker can satisfy certain intentions, and so on." (Cohen, Morgan and Pollack, 1990:3)

The work presented in this thesis identifies the nature of intention as being crucial to the understanding and explanation of how dialogue works. This was emphasised again by Bratman (1990), a major contributor to the symposium, who uses the concept of intention to characterise both our actions and our minds. He focuses on what it is to have future directed intentions, that is, intending to do something rather than doing something intentionally and the work of Cohen and Levesque (1990) contributing to the same symposium, takes up this focus in relation to how persistence and commitment relate to future directed intention. Their work provides valuable and thought provoking insights to this difficult area of study. The emphasis of my work is more modest and can be viewed as a refinement, as its focus is on intention in action. Viewing speech as action and individual utterances as intentions in action, an attempt has been made at a finer grained study.

The planning approaches to communication that appear to continue to dominate the research, also relate to future directed intentions. While Pollack (1990) moves away from the traditional AI approaches to planning, viewing plans as complex mental attitudes, these still relate to the future directed intentions of agents. My treatment and application of a planning component is different. Consistent with viewing the characteristic of intention as intention in action, my model applies a planning component to this characteristic of intentional behaviour and utterances themselves are viewed as being planned intentional actions of the agent.

A related and continuing area of interest is how plans of agents are recognised by other agents within the interaction. This has not been dealt with explicitly in this work as it is related generally to the future directed intentions of agents rather than the intention in action of agents. What this work has attempted to focus on is how agents might recognise and understand the intention in action of other agents by what is



presented in the context of the interaction as well as in the content of the other agent's utterances.

Applications embodying or based on speech-act theory continue to proliferate as much current work is based on some variation of this theory. Vanderveken (1990) puts forward a proposal for the unification of speech-act theory and a formal semantics. A cause for concern in his proposal, as well as in some other discussions of speech-act theory is that speech-act theory appears to be accepted without qualification. However, a significant body of criticism has arisen over the years and many questions about this approach remain unanswered (cf. Levinson, 1983). The relevance of speech-act theory to this work is that utterances are viewed as rational action, that is, intentional action that is motivated by particular beliefs, goals and plans.

The features considered in this work relate to high level-dialogue. Kiss has suggested that such features might find a place in the design of any interactive computer system but that where systems need to maintain an explicit model of the user and to reason about the dialogue itself then applications will need these features of high level dialogue.

## **6.9 Epilogue**

Bach (1990: 400) suggests that in the research task there is a tension between the guiding principles being too broad while the detailed implementations are too narrow. He closes his paper by saying that the dilemma for researchers is how to devise models that are neither too vague and uninformative nor too constrained or specific.

This work is an attempt to look at some features of dialogue from a less orthodox perspective but within the context created by the dilemma of these competing principles.

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*Appendix 1 - Agents' Belief Sets*

The Bookseller's goal beliefs:

(SELL, BOOKSELLER, BOOK) & (WANT, BOOKSELLER, a, b)  
& ((BUY, CUSTOMER, BOOKS) = a) & ((HIGHVAL, BOOKS) = b)

The Bookseller's general beliefs:

(~KNOW, BOOKSELLER) & (IF a) & ((WANTS, CUSTOMER, HELP) a)  
(~KNOW, BOOKSELLER) & (IF a, b, c, d) & ((KNOW, CUSTOMER) = a)  
& (PAPERCOVERS, BOOKXYZ) = b) & (HARDCOVER, BOOKXYZ) = c)  
& (VALUE£15, BOOKXYZ) = d))

(B, SELF)

(B, I)

(C, YOU)

The Customer's goal beliefs:

(HAVE, CUSTOMER, BOOKXYZ) & (WANT, CUSTOMER, BOOKXYZ)  
& (IF a, b, c (BUY, CUSTOMER, BOOKXYZ)  
& ((HAVE, BOOKSELLER, BOOKXYZ) = a)  
& ((PAPERBACK, BOOKXYZ) = b)  
& ((VALUE£15, BOOKXYZ) = c)

The Customer's general beliefs:

(~KNOW, CUSTOMER) & (IF a, b, c) &  
((HAVE, BOOKSELLER, BOOKXYZ) = a)  
& ((PAPERCOVERS, BOOKXYZ) = b) & ((VALUE£15, BOOKXYZ) = c)

(C, SELF)

(C, I)

(B, YOU)

General beliefs possessed by both agents:

(C, CUSTOMER)

(B, BOOKSELLER)

(B, SELF)

(SELLS, BOOKSELLER, BOOKS)  
(BUYS, CUSTOMER, BOOKS)  
(XYZ, BOOK)  
(PAPERBACK, BINDING)  
(HARDCOVERS, BINDING)  
(COST, VALUE)  
(VALUE, COST)  
(MONEY, VALUE)  
(COST, BOOKS, MONEY)  
(HAVE, STATE)  
(SOLD, STATE)  
(KNOW, STATE)  
(~KNOW, STATE)  
(POSSESS, STATE)  
(BOOKXYZ, DEF/SING)  
(BOOKXYZ's DEF/PL)  
(BOOK, INDEF/SING)  
(BOOKS, INDEF/PL)  
("CAN", MOD/AUX<sub>poss</sub>)  
(BOTH, DET)

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*Appendix 2 - Plan-method Definitions*

**NAME:** WANT  
**OBJECT:** ?  
**FROM:** ?  
**TO:** ?  
**ACTION:** ((POSSESS (OBJECT)(STATE))(SATISFIED (STATE)))

**NAME:** BUY  
**OBJECT:** ?  
**FROM:** ?  
**TO:** ?  
**ACTION:** EXCHANGE (MONEY FOR OBJECT)

**NAME:** HELP  
**OBJECT:** ?  
**FROM:** ?  
**TO:** ?  
**ACTION:** ((FROM = OFFER-ASSISTANCE) (TO = ACCEPT-ASSISTANCE))

**NAME:** EXCHANGE  
**OBJECT:** ?  
**FROM:** ?  
**TO:** ?  
**ACTION:** ((TRANSFER OF OBJECT (FROM ? TO ?))  
(AFFIRM EXCHANGE (ASSERT)))

**NAME:** SELL  
**OBJECT:** ?  
**FROM:** ?  
**TO:** ?  
**ACTION:** EXCHANGE (OBJECT FOR MONEY)

**NAME:** PAY  
**OBJECT:** ?  
**FROM:** ?  
**TO:** ?  
**ACTION:** EXCHANGE (MONEY FOR OBJECT)

**NAME:** OFFER-ASSISTANCE  
**OBJECT:** ?  
**FROM:** ?  
**TO:** ?  
**ACTION:** (ASK (KNOWIF-QUESTION = Y/N QUERY  
(MOD/AUXpossib. "CAN")))

**NAME:** REQUEST-ASSISTANCE  
**OBJECT:** ?  
**FROM:** ?  
**TO:** ?  
**ACTION:** ((ASK (KNOWIF-QUESTION = Y/N QUERY))  
(KNOWINFO-QUESTION =  
WH-QUERY)))



NAME: ACCEPT-ASSISTANCE  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: (ASSERT-AFFIRMATIVE (FORMULAIC "YES PLEASE"))

NAME: GET-INFO  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: ASK KNOWINFO-QUESTION

NAME: GIVE-DIRECTION  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: COMMAND

NAME: ~KNOW  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: ((ASK (KNOWIF-QUESTION = Y/N QUERY))  
(KNOWINFO-QUESTION = WH-QUERY)))

NAME: HAVE  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: (POSSESS (STATE))

NAME: ASSERT  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: (DECLARE (INFORMIF = (AFFIRMATIVE = YES, NEGATIVE = NO))  
(INFORMINFO = OTHER))

NAME: ASK  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: ((QUESTION ((ASK (KNOWIF-QUESTION = Y/N QUERY))  
(KNOWINFO-QUESTION WH-QUERY)))

NAME: Y/N QUERY  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: ((TO = ASK (KNOWIF-QUESTION))  
(FROM = (REPLY (DECLARE, ASK, COMMAND))))

NAME: WH-QUERY  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: ((TO = ASK (KNOWINFO-QUESTION))  
(FROM = (REPLY (DECLARE, ASK, COMMAND)))

NAME: REPLY  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: (FROM = DECLARE, COMMAND, ASK)

NAME: DECLARE  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: (DECLARE (INFORMIF =(AFFIRMATIVE =YES,NEGATIVE = NO))  
(INFORMINFO = OTHER))

NAME: COMMAND  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: ORDER

NAME: TAKE  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: TRANSFER OBJECT FROM ? TO ?

NAME: TRANSFER  
OBJECT: ?  
FROM: ?  
TO: ?  
ACTION: OBJECT MOVES FROM ? TO ?

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*Appendix 3 - CONTEXTFRAME Definitions*

<b>CASE-NAME:</b>	AGENT
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	((SELF = (PRO PERSON "I")) (OTHER = (PRO PERSON "YOU", "HE", "SHE", "IT" "THEY", "THEM") ANIMATE))
<b>ACTION/STATE:</b>	((INTERPRET ("I" = "YOU") ("YOU" = "I")("HE", "SHE", "IT" = ?) ("THEY", "THEM" = ?)))
<b>SUBSIDIARY FUNCTIONS:</b>	NIL
<b>CASE-NAME:</b>	CO-AGENT
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	((SELF = (PRO PERSON "I")) (OTHER = "THEY", "THEM") (ANIMATE))
<b>ACTION/STATE:</b>	((INTERPRET ("I" = "YOU") ("YOU" = "I")("HE", "SHE", "IT" = ?) ("THEY", "THEM" = ?)))
<b>SUBSIDIARY FUNCTIONS:</b>	NIL
<b>CASE-NAME:</b>	INSTRUMENT
<b>IDENTITY-FILLERS:</b>	?X?
<b>RESTRICTIONS:</b>	(INANIMATE, ANIMATE)
<b>ACTION/STATE:</b>	NIL
<b>SUBSIDIARY FUNCTIONS:</b>	NIL
<b>CASE-NAME:</b>	THEME
<b>IDENTITY-FILLERS:</b>	?X?
<b>RESTRICTIONS:</b>	(SUBGOAL-ELEMENT, BELIEF-ELEMENT)
<b>ACTION/STATE:</b>	NIL
<b>SUBSIDIARY FUNCTIONS:</b>	NIL
<b>CASE-NAME:</b>	CO-THEME
<b>IDENTITY-FILLERS:</b>	?X?
<b>RESTRICTIONS:</b>	(SUBGOAL-ELEMENT, BELIEF-ELEMENT)
<b>ACTION/STATE:</b>	NIL
<b>SUBSIDIARY FUNCTIONS:</b>	NIL
<b>CASE-NAME:</b>	EXPERIENCER
<b>IDENTITY-FILLERS:</b>	SELF, OTHER
<b>RESTRICTIONS:</b>	((SELF = (PRO PERSON "I")) (OTHER = (PRO PERSON "YOU", "HE", "SHE", "IT" "THEY", "THEM") (ANIMATE))
<b>ACTION/STATE:</b>	((INTERPRET ("I" = "YOU")("YOU" = "I") ("HE", "SHE", "IT" = ?)("THEY", "THEM" = ?)))
<b>SUBSIDIARY FUNCTIONS:</b>	NIL

CASE-NAME: BENEFICIARY  
IDENTITY-FILLERS: SELF, OTHER  
RESTRICTIONS: ((SELF = (PRO PERSON "I")) (OTHER =  
(PRO PERSON "YOU", "HE", "SHE", "IT"  
"THEY", "THEM") (ANIMATE))  
ACTION/STATE: ((INTERPRET ("I" = "YOU")  
("YOU" = "I")("HE", "SHE", "IT" = ?)  
("THEY", "THEM" = ?)))  
SUBSIDIARY FUNCTIONS: NIL

CASE-NAME: AT-LOCATION  
IDENTITY-FILLERS: SELF, OTHER, OBJECT  
RESTRICTIONS: (PLACE, ANIMATE, INANIMATE)  
ACTION/STATE: ((?X? WITH ?Y?) (?X? WITH ?Z?))  
SUBSIDIARY FUNCTIONS: NIL

CASE-NAME: TO-LOCATION  
IDENTITY-FILLERS: SELF, OTHER, OBJECT  
RESTRICTIONS: (PLACE, ANIMATE, INANIMATE)  
ACTION/STATE: (TO ?X?)  
SUBSIDIARY FUNCTIONS: NIL

CASE-NAME: FROM-LOCATION  
IDENTITY-FILLERS: SELF, OTHER  
RESTRICTIONS: (PLACE, ANIMATE, INANIMATE)  
ACTION/STATE: (FROM ?Y?)  
SUBSIDIARY FUNCTIONS: NIL

CASE-NAME: AT-POSSESSION  
IDENTITY-FILLERS: SELF, OTHER  
RESTRICTIONS: (ANIMATE)  
ACTION/STATE: (WITH ?X?)  
SUBSIDIARY FUNCTIONS: NIL

CASE-NAME: TO-POSSESSION  
IDENTITY-FILLERS: SELF, OTHER  
RESTRICTIONS: (ANIMATE)  
ACTION/STATE: (TO ?X?)  
SUBSIDIARY FUNCTIONS: NIL

CASE-NAME: FROM-POSSESSION  
IDENTITY-FILLERS: SELF, OTHER  
RESTRICTIONS: (ANIMATE)  
ACTION/STATE: (FROM ?X?)  
SUBSIDIARY FUNCTIONS: NIL

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*Appendix 4 - Definitions of cases used in the model*

<u>CASE</u>	<u>DEFINITION</u>
AGENT	<ul style="list-style-type: none"> <li>• the agent that caused the event to happen.....intentional causation.</li> </ul>
CO-AGENT	<ul style="list-style-type: none"> <li>• a secondary agent in a dialogue...the one addressed.</li> </ul>
INSTRUMENT	<ul style="list-style-type: none"> <li>• force or tool used in causing the event.</li> </ul>
THEME	<ul style="list-style-type: none"> <li>• the thing that the utterance is about.</li> </ul>
CO-THEME	<ul style="list-style-type: none"> <li>• a secondary theme in an exchange.</li> </ul>
EXPERIENCER	<ul style="list-style-type: none"> <li>• the person who is doing the perceiving or is in a psychological state.</li> </ul>
BENEFICIARY	<ul style="list-style-type: none"> <li>• the person for whom some act is done.</li> </ul>
AT-LOCATION	<ul style="list-style-type: none"> <li>• the state/value on some dimension where the event occurred.....location.</li> </ul>
TO-LOCATION	<ul style="list-style-type: none"> <li>• final value in a state change...destination or final location.</li> </ul>
FROM-LOCATION	<ul style="list-style-type: none"> <li>• original value in a state change...original location or source.</li> </ul>
AT-POSSESSION	<ul style="list-style-type: none"> <li>• the state/value on some dimension where the event occurred.....location.</li> </ul>
TO-POSSESSION	<ul style="list-style-type: none"> <li>• final possessor or recipient.</li> </ul>
FROM-POSSESSION	<ul style="list-style-type: none"> <li>• original possessor.</li> </ul>

Some of these case definitions are borrowed from Allen (1987: 203) and are used as he defines them while others have been adapted to suit the purposes required by the model proposed in this research.

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*Appendix 5 - Scripts*

Schank & Abelson (1977) view understanding as the fitting of new information into a previously organized view of the world. A great deal of work both with sentence comprehension and the understanding of prose within different contexts suggests that single words can set up expectations about what is likely to be encountered in the remainder of the sentence or the rest of the passage (cf. Halliday & Hasan, 1976). Single sentences or utterances can set up expectations about what is to follow in the rest of the story or conversation.

Schank & Abelson (ibid.) suggest that these expectations characterize world knowledge which bears on any given situation. For them, a 'script' encapsulates this world knowledge and is a structure that describes an appropriate sequence of events within particular contexts. It is a structure which is composed of slots and specific requirements about what can fill these slots. The whole is interconnected and what fills one slot can affect the contents of other slots. Scripts are a way of dealing with stylized everyday situations which are subject to little change.

Schank & Abelson view scripts as predetermined, stereotyped sequences of actions defining well known situations. There are scripts for eating in restaurants, for birthday parties, cricket matches, classrooms and boardroom meetings, in fact they are extremely numerous, and each script has its players who assume different roles in the action. A script is adopted from the viewpoint of each participant and changes from differing viewpoints. They have a role in the understanding of natural language (Lehnert, 1979).

Schank has suggested that paragraphs within a text can be represented in memory by causal chaining (Schank & Abelson, 1977: 423).

This theory implies that for a passage of text or a story to be understood, inferences must be drawn to connect each conceptualisation to all the others in the story that relate to it. This connection process is also said to be operative in the use of scripts, and in fact facilitates the processing of a script. Each act in the script is

connected by this causal chaining process in that each step of the action in the sequence results in conditions becoming operative for the next step to occur. Prior steps in the script must be completed satisfactorily for the latter ones to be enacted. If not, the hitches and discrepancies which may occur, have to be dealt with, perhaps requiring a new action being generated to get things moving again but not prescribed by the script.

The general format for a script is not a list of events but a set of paths linked at certain crucial points linked by a causal chain. Certain sets of circumstance define when a specific script is appropriate or necessary to be called into play. In the example in this Appendix, a sketch of a script for a restaurant from the customer's point of view is shown. In this script actions are specified in terms of the primitive ACTS of conceptual dependency theory (Schank, 1972). Schank proposed a theory of semantics in which the meanings of words are represented by semantic primitives. They include the following items: PTRANS - the transfer of the physical location of an object, ATRANS - the transfer of an abstract relation such as possession, MTRANS - the transfer of mental information, MOVE - movement of a body part, PROPEL - application of a physical force to an object, and MBUILD - the construction of new information.

**script:** restaurant

roles: customer, waitress, chef, cashier

reason: to get food so as to go up in pleasure and down in hunger

scene 1: entering

PTRANS self into restaurant

ATTEND eyes to where empty tables are

MBUILD where to sit

PTRANS self to table

MOVE to sit down

scene 2: ordering

ATrans receive menu

MTRANS read menu

MBUILD decide what self wants  
MTRANS order to waitress

scene 3: eating

ATRANS receive food  
INGEST food

scene 4: exiting

MTRANS ask for cheque  
ATRANS receive cheque  
ATRANS tip to waitress  
PTRANS self to cashier  
ATRANS money to cashier  
PTRANS self out of restaurant

A Sketch of a script for a restaurant from the customer's point of view. (Taken from Scripts, Plans, and Knowledge by Roger C. Schank and Robert P. Abelson - reading 26 in Thinking: Readings in Cognitive Science, edited by P. N. Johnson-Laird and P. C. Wason; C.U.P. 1977).

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*Appendix 6 - Applications of model to further scenarios***6a Negotiations between management and union representatives**

In this scenario management are wanting to introduce a new disciplinary procedure replacing practices which have previously been dealt with by custom and practice. The new procedure does away with an external appeals procedure and keeps any final appeal on any matter of discipline within the organisation which becomes the responsibility of the employers. The union side wish to retain the freedom to make a final appeal to an outside body made up of national employers and union representatives which in their view would be fairer and a more favourable option for their members. The external appeals would be made to a body called the Joint Negotiating Committee whereas the body in house to which appeals would be heard is called The Committee. The following is a constructed-data dialogue between the chief negotiators of both sides on this issue.

- |                   |  |
|-------------------|--|
| <b>Union Neg.</b> | Our members have always known that they can make an appeal to the JNC as a last resort.  |
| <b>Man. Neg.</b>  | Your members are not losing anything. They will be able to make an appeal to The Committee.  |
| <b>Union Neg.</b> | This is not good enough. The Committee are not likely to disagree with Management are they? Our members will not believe they are getting a fair hearing.  |
| <b>Man. Neg.</b>  | No that's not the case. The Committee are very experienced in these matters. They understand the issues and will be able to deal with them appropriately. You can reassure your members that they are competent to deal with appeals and they will get a fair hearing. |

**Man. Neg.**            Anyhow, we don't really see your problem. You have never ever taken an appeal to the JNC have you? So what difference does this change really make?

**Union Neg.**        Its a change in members conditions of service. They don't like this change and believe they will lose out. They believe they will get a fairer hearing before the JNC than they will before their own Employers.

**The Union goals in this scenario**

To obtain a clause in the new management disciplinary procedure to allow members to make an appeal to an external body such as the JNC or to ACAS. To get Management to change their mind and to incorporate this in their procedure.

**The Management goals in this scenario**

Get the Union to agree that appeals are no longer made to an external body but to the Committee, the Employing body and persuade them to accept this new disciplinary procedure.

**The goal-tree of the union negotiator**

(GOAL (MAKE, MEMBERS, APPEALS) &  
(APPEALS, MEMBERS, JNC))

(ASSERT (MAKE, MEMBERS, APPEALS) &  
(APPEALS, MEMBERS, JNC) &  
(UNACCEPTABLE))

(ASSERT (~DISAGREE, COMMITTEE, MANAGEMENT) &  
(~GET, MEMBERS, (HEARING, FAIR)))

(ASSERT (~WANT, MEMBERS, CHANGE) &

(BELIEVE, MEMBERS, a, b,)

((LOSE, MEMBERS, PRESENTCONDITION.) = a)

((~GET, MEMBERS (HEARING, FAIR)) = b))

(ASSERT (BELIEVE, MEMBERS, a, b,)

((GOOD, PRESENTCONDITION.) = a)

((BAD, NEWCONDITION) = b))

**The goal-tree of the management negotiator**

(GOAL (AGREE, UNION, NEWCONDITION) &

(ACCEPT, UNION, CHANGE))

(ASSERT (~LOSE, UNIONMEMBERS, ANYTHING) &

(MAKE, UNIONMEMBERS, APPEALS) &

(APPEALS, UNIONMEMBERS, COMMITTEE))

(ASSERT (~TRUE (~DISAGREE, COMMITTEE, MANAGEMENT) &

(~GET, MEMBERS, (HEARING, FAIR))

(COMMITTEE, EXPERIENCED, (APPEAL, HEARINGS)) &

(COMMITTEE, COMPETENT, (APPEAL, HEARINGS)) &

(REASSURE, UNIONMEMBERS, a,b,c)

((COMPETENT, COMMITTEE, (APPEAL, HEARINGS)) = a)

((GET, UNIONMEMBERS, (HEARING, FAIR)) = b))

(ASSERT (~UNDERSTAND, MANAGEMENT) &

(~WANT, UNIONMEMBERS, CHANGE)

(~TAKEN, UNION (APPEAL, UNIONMEMBERS, JNC)))

(QUESTION (~KNOW (DIFFERENCE, NEWCONDITION,  
PRESENTCONDITION))

6b The communicative interaction between a teacher and two pupils.

In this scenario I have departed from using a constructed-data dialogue and have selected a dialogue from the literature attributing goals and objectives to the participants. This has served two purposes. An attempt to apply the principles of the model to an aspect of conversational analysis and to see how far the model might relate to this type of interaction. The dialogue is taken from "Discourse Analysis" by Michael Stubbs (1983: pp.54-5). The transcript of the tape-recording of the dialogue is on the left and on the right are reproduced the metacommunication functions Stubbs ascribes to this dialogue.

The dialogue between a teacher and two pupils

Transcript of tape-recording	Metacommunication functions
Teacher: right,	Attracts pupils' attention
as I was saying - -	Attracts pupils attention
the subject of the discussion	
is capital punishment -	Specifies topic of discussion
now -	Attracts pupils attention
you don't understand what	
this means	Checks pupils'
	understanding
capital punishment - is when	

	- a murderer	Defines term
	do you know what a	
	murderer is -	
	a murderer	Repeats to check understanding
<b>Pupil 1:</b>	yes	
<b>Teacher:</b>	if a man kills another man	
<b>Pupil 1:</b>	ah yes yes	
<b>Teacher:</b>	he is a murderer -	Defines a word
	then - when - a murderer is	
	arrested - and he has a	
	trial - then what happens to	
	him afterwards -	
	what happens after that	Reformulates to check understanding
<b>Pupil 1:</b>	he has a punishment	
<b>Teacher:</b>	yes he is punished	Corrects pupil's language
<b>Pupil 1:</b>	punished	
<b>Teacher:</b>	now -	Attracts pupils' attention
	what punishment do you	
	think he should get?	
<b>Pupil 2:</b>	prison	
<b>Teacher:</b>	prison	Checks his own understanding or shows attention
<b>Pupil 2:</b>	(makes strangling gesture)	
<b>Teacher:</b>	can you tell what - explain	Explicitly controls amount of speech

<b>Pupil 2:</b>	they put a rot	
<b>Teacher:</b>	a rope	Corrects pupil's language
<b>Pupil 2:</b>	a rope - around his neck	
<b>Teacher:</b>	yes	Shows attention
<b>Pupil 2:</b>	and hang him	
<b>Teacher:</b>	and hang him	Repeats to check his own understanding or show attention
	so ah we've got two different ideas here	Summarizes

**The teacher's goal**

The goal ascribed to the teacher in this scenario is to introduce and to discuss the concept capital punishment.

**The pupils goal**

This dialogue presents the model with an apparent problem immediately as it is difficult to ascribe any goals to the pupils prior to the commencement of the dialogue. The pupils are likely to be in a lesson that they have to attend and could be viewed as passive participants to the interaction. It is one of those dialogues that reveals the nature of the power relationships that can exist between participants to an interaction and the status and obligations these relationships might represent. However, that the pupils in this action are only passive participants is not necessarily the case.

Though it may not be possible to identify any communicative goals for them to pursue prior to the commencement of this interaction these can be seen to emerge in response to the teacher's demands on their thought and attention. The pupils are required to respond and they do so in a thoughtful and intelligent manner according to their beliefs and what knowledge they have available to them. Though the pupils are

active in the dialogue it is not one that has been initiated by them but they co-operate and engage with the teacher which can be interpreted as intentional and therefore goal-motivated behaviour. The general goal of the pupils then, can be interpreted as co-operating with the teachers questions and answers. Their 'conversational goals' are formed and made in response to the teachers questions.

Stubbs suggests that this dialogue is revealing for the reason that it shows clearly some of the strategies which a teacher employs to keep in touch with pupils. The ascribing of these strategies or metacommunicative functions to the teacher, though they may be highly accurate, are nevertheless made by subjective assessments or judgements. Stubbs describes these strategies as attracting attention, specifying topic, checking understanding, and defining terms. In terms of my model these strategies would be carried out as ASSERT or QUESTION type utterances.

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**Appendix 7.- The Turn-taking Model of Sacks, Schegloff and Jefferson**

It has been noted that turn taking is used for many human activities other than conversation (Sacks, Schegloff and Jefferson, 1973). Turn taking is used for the ordering of moves in games, for allocating political office, for regulating traffic at intersections and so on. It is evident that it is a prominent characteristic of social organization and Sacks et al., suggest:

"For socially organized activities, the presence of turns suggests an economy, with turns for something being valued, and with means for allocating them affecting their relative distribution, as they do in economies" (ibid., 1973: 696)

What concerns us here is the distribution of turns at talk and the way in which speakers regulate and coordinate them. The data of conversation analysis make increasingly plain the fact that turn-taking must be organized. Normally, one party speaks at a time though the speakers vary and so does the size of the turn. The ordering of turns between the speakers also varies and transitions seem finely coordinated. It becomes evident that there are techniques for allocating turns and also for the construction of utterances.

Sacks et al., describe a system for turn-taking for conversation in terms of two components and a set of rules.

**Component 1 - Turn-Constructional Component**

There are various unit-types with which a speaker may set out to construct a turn. Unit-types for English include sentential, clausal, phrasal, and lexical constructions. Instances of the unit-types so usable allow a projection of the unit-type under way, and what, roughly, it will take for an instance of that unit-type to be completed. Unit-types that lack the feature of projectability may not be usable in the same way.

For the unit-types a speaker employs in starting the construction of a turn's talk, the speaker is initially entitled, in having a "turn", to one such unit. The first possible completion of a first such unit constitutes an initial transition-relevance place. Transfer of speakership is coordinated by reference to such transition-relevance places, which any unit-type instance will reach.

**Component 2 - Turn- Allocational Component**



Turn-allocational techniques are distributed into two groups: (a) those in which next turn is allocated by current speaker selecting a next speaker; and (b) those in which a next turn is allocated by self selection.

The following are the set of basic rules governing turn-construction, providing for the allocation of a next turn to one party, and coordinating transfer so as to minimize gap and overlap. For any turn:

1. At initial turn-constructural unit's initial transition-relevance place,
  - (a) If the turn-so-far is so constructed as to involve the use of a "current speaker selects next" technique, then the party so selected has rights and is obliged to take next turn to speak, and no others have such rights or obligations, transfer occurring at that place.
  - (b) If the turn-so-far is so constructed as not to involve the use of a "current speaker selects next" technique, self-selection for next speakership may, but need not, be instituted, with first starter acquiring rights to a turn, transfer occurring at that place.
  - (c) If the turn-so-far is so constructed as not to involve the use of a "current speaker selects next" technique, then current speaker may, but need not, continue, unless another self-selects.
2. If, at initial turn-constructural unit's initial transition-relevance place, neither 1(a) nor 1(b) has operated, and, following the provision of 1(c), current speaker has continued, then the Rule-set (a) - (c) reapplies at next transition-relevance place, and recursively at each next transition-relevance place, until transfer is effected (Sacks et al., 1973: 702-3; 1978: 12-13).

The rules of Sacks et al's model (hereafter Sack's model) are so ordered that they constrain each of the options provided by the rules. Lower priority options constrain the use of higher priority options. The options of each of the rules are constrained by the options of other rules in the set regardless of whether those options are employed. Thus the operation of the option rule 1a is constrained by the presence in the set of rule 1b and so on. The rules provide an ordering for the application of the two turn-allocational components thus making it compatible with the requirement of 'one speaker at a time'. Without the inclusion of both components being ordered in this

way there would be the potential for violation and of more than one party being selected at any given point.

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# Appendix 8 - The conversation between Mary and John from Power's

What follows is an example of the dialogue that Power's program produces. In this example, the preliminary situation was defined as follows. JOHN OUT, MARY IN, BOLT UP, DOOR SHUT. John is able to see all the objects but Mary is blind and can not see any of them. John can move, slide the bolt but cannot push the door. Mary can perform all three actions. John believes that, 1) if you move, nothing happens; 2) if you push the door, it changes position; and 3) if you slide the bolt, nothing happens. Mary believes that, 1) if you move when the door is open, you change position; 2) if you push the door, it changes position; 3) if you slide the bolt, nothing happens. John has been given the goal to get himself in, whereas Mary has no goal.

The adapted example is reproduced from Power's (1974: 30-31) study and includes his annotated notes. It is only the first part of the conversation.

- 1 JOHN: MARY.
- 2 MARY: YES.
- 3 JOHN: I WANT TO SUGGEST A GOAL.
- 4 MARY: GO AHEAD.
- 5 JOHN: WILL YOU HELP ME TO GET IN.
- 6 MARY: BY ALL MEANS.

- \*The robots have now agreed to cooperate to achieve
- \*John's goal. Mary has learned John's goal, and
- \*John has learned that she is willing to help. If Mary
- \*had been given a goal different from John's she would
- \*have refused to help him.

- 7 JOHN: SHALL WE MAKE A PLAN.
- 8 MARY: JOHN.
- 9 JOHN: YES.
- 10 MARY: MAY I ASK YOU SOMETHING.
- 11 JOHN: GO AHEAD.
- 12 MARY: ARE YOU IN.
- 13 JOHN: NO.

- \* Mary interrupted because she did not know whether the
- \* goal was already achieved (she is blind, remember);
- \* had she been cleverer, she would have inferred John's
- \* position from 5. Before selecting a plan to achieve
- \* a goal, a robot always checks that the goal is not yet
- \* attained and that a plan is thus needed. The